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A STUDY OF THE FEASIBILITY OF DEVELOPING OVERLAY MAPS TO INDICATE PERFORMANCE CAPABILITIES OF ORDNANCE EQUIPMENT IN SELECTED WORLD ENVIRONMENTS

Carroll G. Robinson
Howard M. Bunch

June 1962

Contract No.
DA-23-072-ORD-1375
Supplemental Agreement No. 8
Task Order No. 10

OCO R&D Division
OMS COde 5610.11.70100

DEPARTMENT OF ARMY
Project No. 598-09-004

Southwest Research Institute

San Antonio, Texas

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PUBLICATION REVIEW

This report has been reviewed and approved for publication. It is published only for the general dissemination of knowledge and does not necessarily reflect the official viewpoint of the Department of the Army.

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AMC Detachment No. 1 (formerly of ORDTB-EO)

ABSTRACT

This document was an evaluation of a specific methodology (see Appendix F) for attempting to predict performance of Ordnance self-propelled vehicles in selected world environments using presently available vehicle test data and world geographical data as inputs. Vehicles selected for evaluation were: tank, 90mm gun, full-tracked, M48; carrier, personnel, armored, full-tracked, M113; truck, cargo, 2-1/2-ton, M35; and carrier, light weapons, infantry, 4 X 4, M274. The South Asian desert was the geographical area used in the evaluation.

General performance limits of a vehicle can be plotted for a given area. However, the degree of reliability of these plots is severely limited by the lack of definitive data relating vehicle performance to precise soil and terrain definitions. Suggestions were given for improving the system.

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I. INTRODUCTION

A. Statement of the Problem

The U. S. Army has long desired the ability to predict the performance capabilities of its equipment at any specified point of the world. This need has been particularly acute in areas of severe environmental extremes.

Presently, Army regulations define the design requirements of all equipment; and to determine whether any item can meet these design requirements, it is tested under a variety of severe terrain and atmospheric conditions. The results of these tests are utilized to make general extrapolations of how the item would perform in a generalized area of the world during any specified month or season. Over the years, there have been attempts to provide aids that would improve the quality of these extrapolations. For example, the Ordnance Corps Envanal program has endeavored to reduce the test results into a simplified presentation of the essential test data, as affected by terrain or environmental conditions. At the same time, the U. S. Army Quartermaster Corps and the U. S. Army Corps of Engineers have been conducting studies designed to present the degree of terrain and climatic analogy between the test sites and other points of the world.

The problem arises as to the reliability of equipment performance extrapolations, based upon the test results and the environmental analogs. Can these data provide satisfactory answers, and if not, what changes should be made to improve the response quality of performance predictions?

It is the purpose of this study to examine equipment environmental test reports and attempt to predict that equipment's performance capabilities as described by Envanal charts in a different world environment, utilizing climatic and terrain analogs developed by the U. S. Army Quartermaster Corps and the U. S. Army Corps of Engineers.

B. Importance of the Study

World War II and subsequent events changed the defense strategy of the United States from an intraterritorial concept to an international concept. As a result, U. S. military forces must be prepared to fight, at a moment's notice, in any world environment. This shift in strategic concept has tremendously increased the burden of Army Staff in selecting the optimum equipment for a given tactical mission in a defined world environment. The burden is also felt in the area of logistics and supply.

It is natural, then, for continuing effort to be expended in attempting to extend, for predictive purposes, the results of equipment tests at selected test sites to anticipated performance capabilities at another point where similar or perhaps other environmental conditions exist.

This study is an evaluation of data that presently exist, using a specific methodology. Its purpose is to highlight areas where further improvement could be realized in the collecting of data at either the test site or in describing the world environment, or both. And therein lies the importance of the study: by attempting to improve upon the cross-link between the two data gathering systems, it will serve as a basis for redirecting research effort toward increasing equipment performance-prediction capabilities under any given set of world conditions.

C. Method of Approach

At the outset, it was decided that the program was to be only an evaluation of methodology (see Appendix F); thus, it was important to select for study an area of the world upon which a complete set of atmospheric and terrain analogs had been prepared. Too, only representative types of Ordnance self-propelled equipment would need be considered, with the requirement, of course, that these vehicles had been subjected to extensive testing under conditions or in areas included in the available analogs.

The South Central Asian desert was selected as the geographical area of study because (1) it has been compared by the analog technique with Yuma Test Station in both the atmospheric and terrain environments, and (2) there is a strong possibility the U. S. Army Transportation Corps will conduct a cross-country operation through the area in the summer, 1963 (Operation Desert Rat).[1] The Transportation Corps expedition would provide an ideal means of verifying the conclusions and recommendations of this study.

The vehicles selected for evaluation were:

(1) Tank, 90mm gun, full-tracked, M48
(2) Carrier, personnel, armored, full-tracked, M113
(3) Truck, cargo, 2-1/2 ton, 6 × 6, M35
(4) Carrier, light weapons, infantry, 4 × 4, M274

The M48 tank was chosen to represent the heavy, track-laying vehicles; the M113 personnel carrier was to represent the light track-laying

[1] U. S. Army Transportation Board Environmental Operations Program, Appendix "C". Minutes of Panel on Environmental Research, Army Committee on Environment. Meeting No. 24, 29-30 August, 1961, Fort Eustis, Virginia

vehicles; the M35 cargo truck was to be representative of the high-speed, wheeled transport vehicles; and the M274 light weapons carrier was chosen to represent the small, low-ground-pressure wheeled vehicles.

With the geographical area chosen and the vehicles selected, the study proceeded as follows:

(1) evaluation of atmospheric data of the South Asian desert and expression of these data in a form permitting correlation with vehicle performance, based upon test results at Yuma Test Station;

(2) analysis of terrain data on the South Asian desert and expression of these data in a form permitting correlation with vehicle mobility, based upon test results at Yuma Test Station;

(3) plotting by graphic methods the vehicle performance capabilities as affected by the atmospheric and terrain environments of the South Asian desert; and

(4) discussing some conclusions of the study and presenting recommendations on improving the value and reliability of the system.

II. ATMOSPHERIC ANALOGS

The purpose of this chapter is (1) to discuss the atmospheric data contained in equipment test reports, (2) evaluate the atmospheric data available on the South Asian desert, and (3) finally, to make a correlation of these data in a manner that is meaningful to prediction of equipment performance in the South Asian desert.

A. Atmospheric Data Contained in Equipment Test Reports

In the equipment reports examined, atmospheric data were found in two sections. The first was data recorded at the vehicle during a test evaluation. Generally, these data were confined to ambient temperatures, wind speed and direction, and occasionally ground temperatures.

The second type of atmospheric data was a "Summary of Weather Data," which condensed the readings for the entire summer in varying forms. A typical summary covered the entire test period and contained the following:

(1) Temperatures

(a) Ambient

(i) Average daily mean (by month)
(ii) Average daily maximum (by month)
(iii) Average daily minimum (by month)
(iv) Number of days with maximum over 100°F (by month)
(v) Number of days with maximum over 105°F (by month)
(vi) Number of days with maximum over 110°F (by month)
(vii) Maximum for period

(b) Surface Temperatures

(i) Number of days with maximum over 130°F (by month)
(ii) Number of days with maximum over 140°F (by month)
(iii) Maximum for period

(2) Wind

(a) Direction - average (by month)
(b) Velocity - average (by month)

(3) Cloud Cover

(4) Solar Radiation

(a) Total for month (gm cal/sq cm)
(b) Maximum hourly rate by month (gm cal /sq cm)

(5) Rainfall, inches by month

(6) Comparison with U. S. Weather Bureau Station, Yuma, Arizona

(a) Mean temperature
(b) Cloud cover
(c) Rainfall

B. Atmospheric Data Available in the South Asian Desert

1. Analogs of Yuma Climate

The main source of atmospheric data was contained in the report Analogs of Yuma Climate in the South Asian Desert.[2] The study included ten analogies (maps) between the Yuma climate and the South Asian desert as follows·

(1) Mean temperature, warmest month
(2) Mean daily maximum temperature, warmest month
(3) Absolute, maximum temperature
(4) Mean daily temperature range, warmest month
(5) Mean temperature, coldest month
(6) Mean daily minimum temperature, coldest month
(7) Mean annual precipitation
(8) Mean dew point, highest month
(9) Mean cloudiness, July
(10) Prevailing wind direction and mean velocity, July

Evaluation of these types of analogs were, as mentioned in the Introduction, one of the primary objectives of this study. In this regard,

(2) Robison, Wm. C., and Arthur V. Dodd, Analogs of Yuma Climate in South Central Asia (India, Pakistan, Afghanistan, Iran), HqQM Research & Development Command, QM Research & Development Center, U S Army, Natick, Mass., 7-83-03-008A, June 1955.

it was apparent at an early stage that only three of the ten analogs would be appropriate for use in making equipment prediction evaluations. The primary reason was that it was impossible to relate the effect of any of the other seven upon vehicle performance, as revealed in the equipment test reports. The analog data finally utilized were:

(1) Mean temperature, warmest month
(2) Mean daily maximum temperature, warmest month
(3) Absolute maximum temperature

Despite the fact that only a limited portion of the analog data was directly translatable to this study, the Quartermaster Corps report indicated the degree of atmospheric analogy that existed between Yuma and the South Asian desert. This information would be helpful in predicting performance if it were known that a piece of equipment would absolutely perform satisfactorily in the Yuma (or similar) climate, and vice versa. The areas of the Yuma-South Asian desert analogy are as follows:

(1) Extensive areas of South Central Asia have summer temperatures analogous to Yuma. Only in the extremely hot Indus Valley of Pakistan and the interior basins of Iran, and in the perennially cool mountains of Kashmir, Afghanistan, and northern Iran are summer temperatures appreciably different from those at Yuma.

(2) Mean annual precipitation falls within some degree of analogy over most of the area.

(3) The combined areas of analogy and semianalogy for mean July cloudiness are approximately the same as for mean annual precipitation.

(4) Mean July wind speeds are analogous or semi-analogous at most of the stations for which values are available, being too high only at some of the coastal stations and in the vicinity of the Seistan Basin near the center of the region.

(5) Summer dew points are analogous in a comparatively narrow band between the humid regions that are subject to maritime influence, and the dry highland regions of Kashmir, Afghanistan, and Iran.

(6) The greatest coincidence of analogy of combined climatic elements is in western Baluchistan, as shown by the records of Panjgur; a similar area of nearly total analogy is found in the Indus River Valley of West Pakistan in the vicinity of Bahawalpur.

The Quartermaster Corps report also pointed out certain other limitations that exist when dealing with comparisons between the atmospheric environment of South Central Asia and Yuma:

(1) There is a lack of quantitative data for large parts of the study region, especially in some of the more arid portions where conditions are most likely to be analogous to Yuma

(2) Significant data of some types are not available for most of South Central Asia Solar radiation, dust count, visibility, gust velocity, type of cloud, rate of corrosion, and frequency of sand and dust storms are among the factors omitted

(3) Data are sometimes not given in a consistent form. Period of record, hours of observation, and method of recording data are several of the discrepancies that were noted

2. <u>Latitude-Longitude Temperature Estimates</u>

Additional data were obtained from the Quartermaster Corps and included latitude-longitude temperature estimates for the country of Iran At each degree of latitude-longitude intersection, estimates of the following data have been made for the month of July

(1) Mean daily temperature
(2) Mean daily maximum temperature
(3) Absolute maximum temperature
(4) Mean daily minimum temperature
(5) Absolute minimum temperature

In addition, the lapse rate of mean temperature was obtained

C. Correlation of Test Data with South Asian Desert Data

In attempting to correlate the equipment test data with that obtained on the South Asian desert, it was found that only temperature information was consistently recorded in both places. Therefore, all further effort was directed toward obtaining, or estimating, significant temperature data. For each station, the following information was considered significant:

(1) Absolute maximum temperature, warmest month (T_{max})
(2) Mean daily maximum temperature, warmest month (T_{mdm})
(3) Mean daily temperature, warmest month ($T_{\bar{x}}$)

At points where an estimate for any of the above were made, the following equations were assumed

	Interior Areas	Coastal Areas
(1)	$T_{max} - T_{\bar{x}} = 3\sigma$	$T_{max} - T_{\bar{x}} = 3\sigma$
(2)	$T_{mdm} - T_{\bar{x}} = 1.5\sigma$	$T_{mdm} - T_{\bar{x}} = 1.55\sigma$

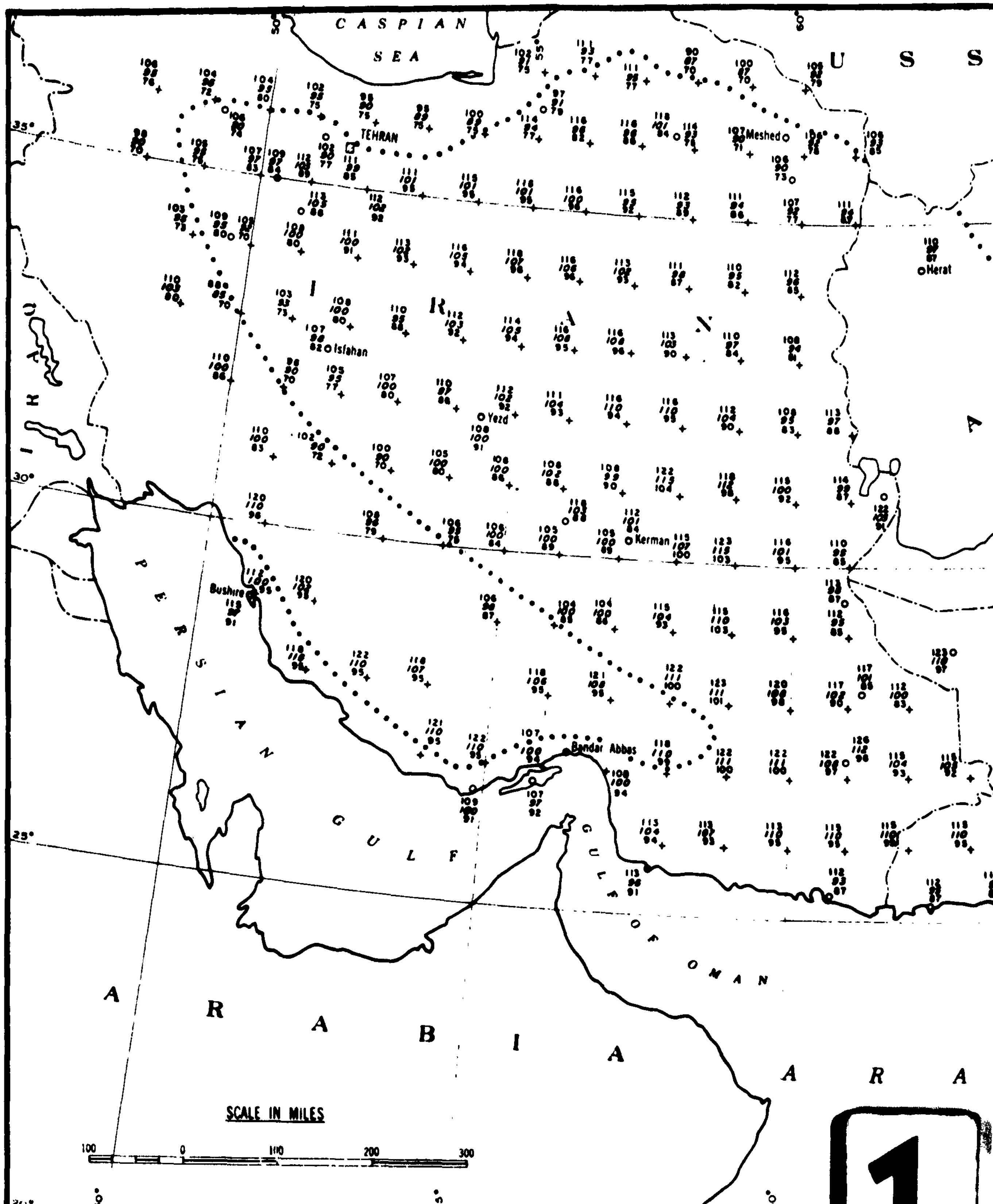
Therefore, with any of the two temperatures known, the third could be easily calculated

The derivation of the above formulae was obtained experimentally by examination of data of those reporting stations from which all three temperature points were known Figure 1 shows the temperatures used in the study The highest reading is the absolute maximum temperature (T_{max}), the middle recording is the mean daily maximum temperature (T_{mdm}), the lowest reading is the mean daily temperature ($T_{\bar{x}}$)

D. Development of Temperature Frequency Distribution Curves

Since all equipment tests attempted to determine the specific temperature at which performance requirements were exceeded, it was necessary to develop a prediction system from which the frequency of occurrence of any desired temperature could be determined Too, it was necessary to make this prediction of temperature occurrence with only three points given absolute maximum temperature, mean daily maximum temperature, and mean daily temperature

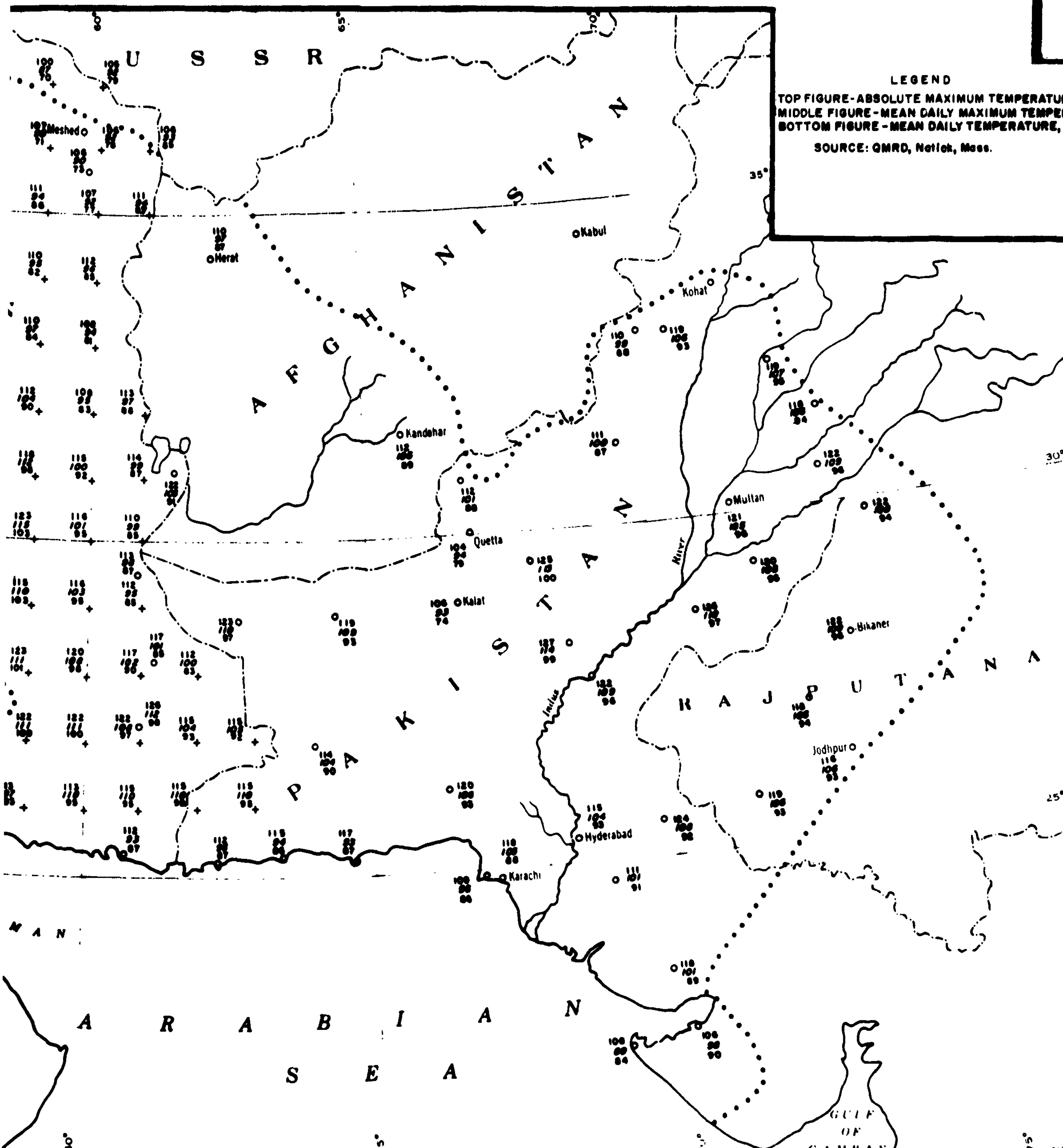
FIGURE I. ABSOLUTE MAXIMUM TEMPERATURES, MEAN DAILY
TEMPERATURES FOR SELECTED POINTS IN SOUTH



1

2

IPERATURES, MEAN DAILY MAXIMUM TEMPERATURES, AND MEAN DAILY .ECTED POINTS IN SOUTH ASIAN DESERT, WARMEST MONTH (JULY)



LEGEND

TOP FIGURE - ABSOLUTE MAXIMUM TEMPERATURE, °F

MIDDLE FIGURE - MEAN DAILY MAXIMUM TEMPERATURE, °F

BOTTOM FIGURE - MEAN DAILY TEMPERATURE, °F

SOURCE: QMRD, Natick, Mass.

Experience has shown that not all temperature distributions will follow a normal distribution. Lackey[3] recognized the limited application of the normal type distribution and suggested the use of a normalized temperature in conjunction with an empirical nomograph for obtaining the frequency distribution. His chart was applicable to any month and any location between 12°N and 70°N latitude. The distribution curves obtained were not reduced to any mathematical forms. And, too, it was required that absolute maximum temperature, mean daily temperature, and absolute minimum temperature be known to utilize the nomograph. Since the absolute minimum temperature was not available, it was not possible to utilize the Lackey system in the study.

As an experimental effort to obtain a relationship which would more closely approximate the distribution, the following cities were selected at random: Bengasi and Tripoli, Libya; Badajoz, Spain; Ashkharad, USSR; El Paso, Texas; Fresno, California; Phoenix and Yuma, Arizona. All stations were in desert areas and were located in the same approximate latitudes as the South Asian desert. The actual distribution of temperatures for these stations was plotted to determine if they would assume a normal distribution curve. It was found that the temperature distribution at Tripoli plotted a normal curve, but the data for the other selected cities would not conform

The errors were plotted and were found to oscillate about the axis in a manner which indicated that a harmonic relationship might be involved. The following relationship was substituted arbitrarily and computed for each distribution

$$P\,(\%) = 100\left[.50 - .50 \cos 180°\left(\frac{T - T_o}{T_{max} - T_o}\right)\right]$$

where

P = Probability

T = Desired temperature

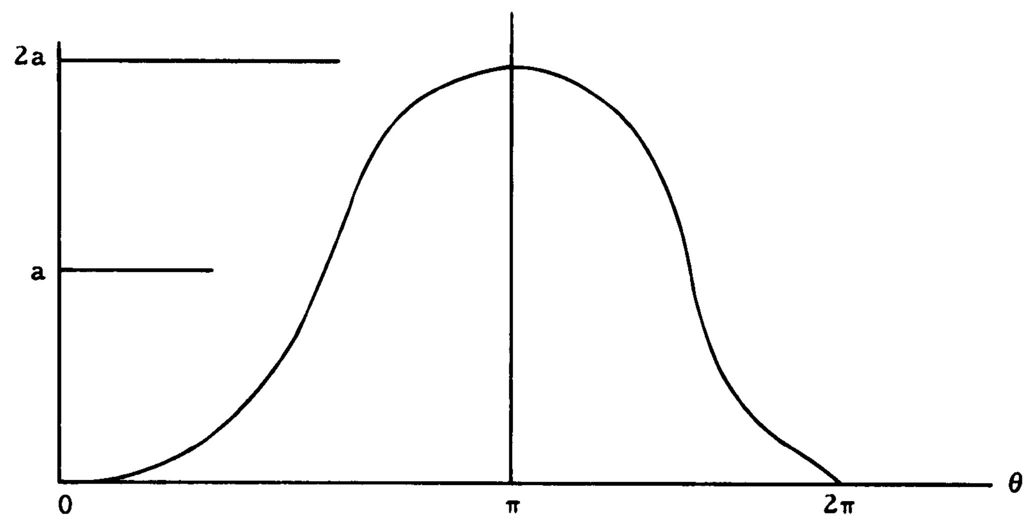
T_o = Absolute minimum temperature

T_{max} = Absolute maximum temperature

(3) Lackey, E. E., "A Method for Assessing Hourly Temperature Probabilities from Limited Weather Records." Bulletin of the American Meteorological Society, June 1960 298-303 pp.

The relationship closely approximated the temperature distributions and indicated the possibility that a trigonometric relation could apply. The next step was to investigate the above equation and attempt to obtain further refinements.

The fact that the curve for the experimental equation was close to the actual curve and contained a cosine term indicated that the basic distribution might possibly be a sine or cosine function. The basic distribution would be the differential of the relation sought. Upon investigation, it was found that the closest form of curve would be the cosine curve with the axis at the midpoint of the curve. When a translation of axis was added, the result was a versed sine curve which, when integrated, produced a relation similar in form to the original but having different terms. The derivation of this relation was as follows:



Total area under cosine curve $= \int_0^{2\pi} (a - a\cos\phi)\, d\phi$

$$= \int_0^{2\pi} a(1 - \cos\phi)\, d\phi$$

$$= a\,(\phi - \sin\phi)_0^{2\pi}$$

$$= a\,(2\pi - 0 - 0 + 0) = 2\pi a$$

$$= 2\pi a$$

The probability is the ratio of the area from 0 to some value of ϕ as a percentage of the total area, $2\pi a$. Therefore

$$P = \frac{\text{area considered}}{\text{total area}} = \frac{a(\phi - \sin\phi)_0^\phi}{2\pi a}$$

$$= \frac{1}{2\pi}(\phi - \sin\phi)_0^\phi$$

Substituting

$$\phi = \left(\frac{T - T_o}{T_{max} - T_o}\right) 2\pi$$

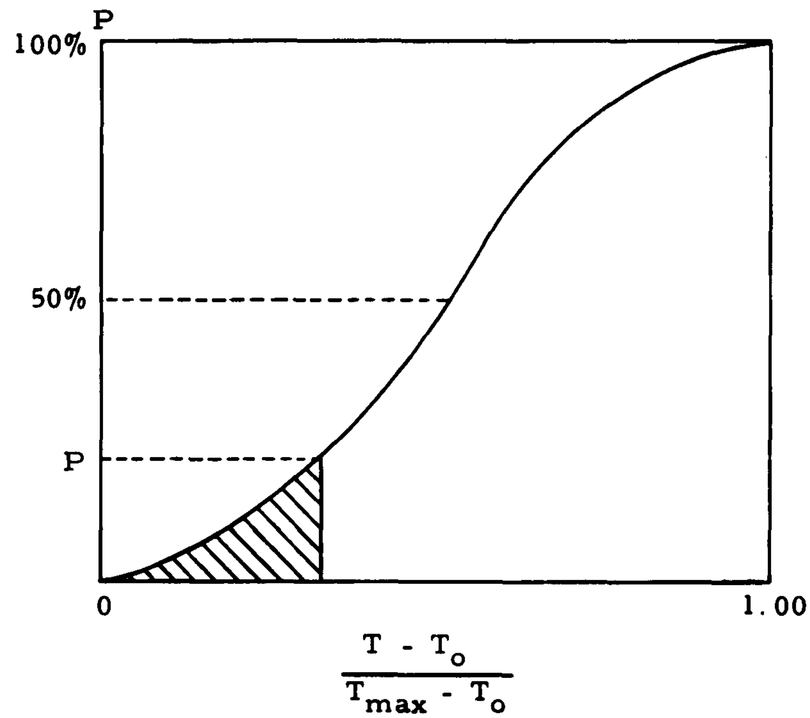
then

$$P = \frac{1}{2\pi}\left[\left(\frac{T - T_o}{T_{max} - T_o}\right) 2\pi - \sin\left(\frac{T - T_o}{T_{max} - T_o}\right) 2\pi\right]$$

$$= \frac{T - T_o}{T_{max} - T_o} - \frac{1}{2\pi}\sin\left(\frac{T - T_o}{T_{max} - T_o}\right) 2\pi$$

$$\text{Probability (\%)} = 100\left[\frac{T - T_o}{T_{max} - T_o} - \frac{1}{2\pi}\sin\left(\frac{T - T_o}{T_{max} - T_o}\right) 2\pi\right]$$

The above equation can be divided into two groups of variables where one is (P) and the other is the ratio $(T - T_o)/(T_{max} - T_o)$. This relation produces a plot as follows:



The curve may be computed once for the various ratios of $(T - T_o)/(T_{max} - T_o)$ and read directly in percentage, or each value may be computed separately. There are only two temperature conditions required, T_{max} and T_o, other than the specified calculation temperature.

By definition, when the mean daily temperature (T_m) is the desired temperature (T), the probability is equal to 50 percent; thus, substituting into Equation (1)

$$50 = 100 \left[\left(\frac{T_m - T_o}{T_{max} - T_o}\right)\right] - \frac{1}{2\pi} \sin\left(\frac{T_m - T_o}{T_{max} - T_o}\right) 2\pi$$

$$50 = 100 \left[\left(\frac{T_m - T_o}{T_{max} - T_o} \right) - 0 \right]$$

$$\frac{1}{2} = \frac{T_m - T_o}{T_{max} - T_o}$$

$$2T_m - 2T_o = T_{max} - T_o$$

$$T_o = 2T_m - T_{max} \tag{2}$$

Now, arbitrarily let $(T_{mdm} - T_o)/(T_{max} - T_o) = .75$, thus obtaining $P = 90.9\%$ for the mean daily maximum temperature (T_{mdm}), and solve as follows

$$T_{mdm} - T_o = 3/4\, T_{max} - 3/4\, T_o$$

$$1/4\, T_o = T_{mdm} - 3/4\, T_{max}$$

$$T_o = 4\, T_{mdm} - 3\, T_{max} \tag{3}$$

Setting Equations (2) and (3) equal and solving for T_{max} gives

$$2T_m - T_{max} = 4T_{mdm} - 3T_{max}$$

$$2T_{max} = 4T_{mdm} - 2T_m$$

$$T_{max} = 2T_{mdm} - T_m \tag{4}$$

Substituting Equation (4) into Equation (2) gives

$$T_o = 2T_m - 2T_{mdm} + T_m$$

$$T_o = 3T_m - 2T_{mdm} \tag{5}$$

Thus, the relations are evolved from which the absolute maximum temperature (T_{max}) and the absolute minimum temperature (T_o) can be estimated by knowing only the mean daily temperature (T_m) and mean daily maximum temperature (T_{mdm}).

Again, the assumptions made for these derivations are as follows:

(1) The distribution is a fixed boundary extreme limit, beyond which a temperature condition is no longer considered normal or could not be expected to occur.

(2) The basic distribution can be expressed as a versed sine distribution or as a translated cosine curve.

(3) The mean daily (T_m) and mean daily maximum temperatures (T_{mdm}) appear at the $(T - T_o)/(T_{max} - T_o)$ ratio values of .50 and .75, respectively. Or, the probabilities are 50 percent and 90.9 percent, respectively, that temperatures will be below these values.

Figure 2 shows a plot of the temperature distributions for the eight stations mentioned eariler against the calculated distribution. As seen, the results give relatively close correlation. The relation appeared very good for those areas which experienced high solar radiation and were not influenced by large bodies of water, or high humidity areas. The notable exception was Ashkharad, U.S.S.R. No attempt was made to explain this deviation.

E. Making the Plot

The final decision was to use the cosine distribution for estimating the interior regions of the South Asian desert. The normal distribution curve was used for the coastal cities, based upon the close correlation between this type of curve and the distribution of the Tripoli, Libya, reporting station.

These distribution curves were then used to estimate the frequence-of-occurrence for various temperatures at the points indicated in Figure 1. The various temperatures that were calculated were those considered critical (see Chapter IV) for the selected vehicles. The probabilities were then plotted, and contour lines were drawn connecting like probabilities (see Chapter IV).

When plotting the temperature probability values, it was known that there was a temperature-elevation relationship. Thus, to assist in constructing the final probability plot of temperature data, the probability map was overlayed on the elevation map, and the contour lines were used to assist in locating the lines of equal temperature probability.

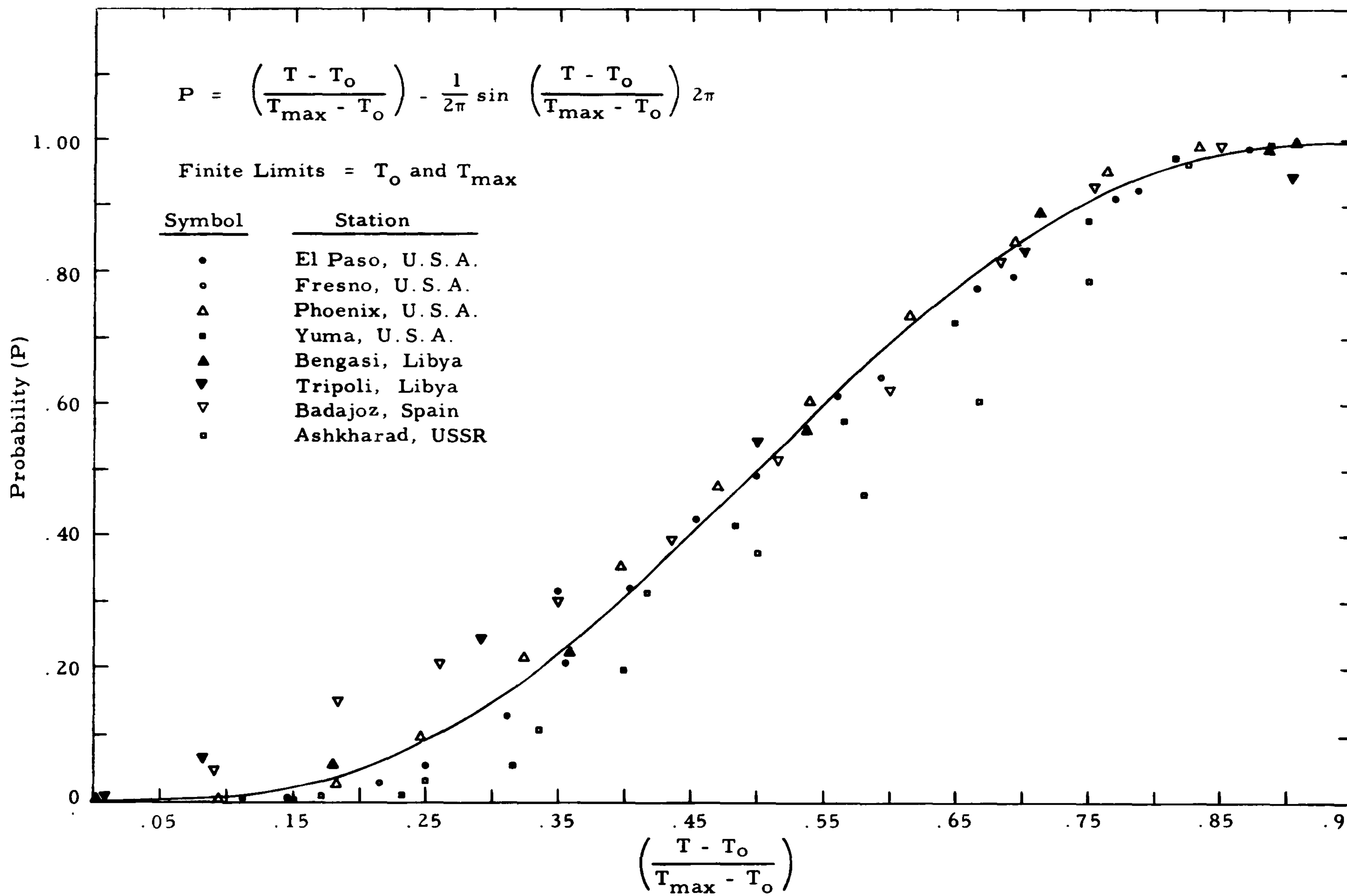


FIGURE 2 PROBABILITY OF TEMPERATURE OCCURENCE, SELECTED STATIONS

III. TERRAIN ANALOGS

A. Discussion of Data of Equipment Tests

1. Test Reports

The input data from the equipment test reports were generally limited to statements made by the test personnel pertaining to performance on the various test courses, because no precise terrain-mobility relationships were recorded. In most instances, the performance was expressed in subjective terms, i.e., "the mobility was poor," or "truck A performed better than truck B." In some cases, especially on the prepared slopes, there were more definitive engineering expressions of performance such as, "slope could only be climbed with 10 psi tire pressure." Occasionally, time was included as a part of the mobility description as, "The vehicle attained 20 mph on Course A."

2. Descriptions of Test Courses

The names and locations of every test course at Yuma Test Station that has been used for mobility evaluations were obtained. The list of these courses is shown as Table 1, together with Yuma Test Station's definition of the terrain description, and with the land-form code descriptions of the courses, as used by the Corps of Engineers (see Appendix A).

It should be noted that there was a great deal of inconsistency between the test course names as shown on the attachment. and their names as given in the report.

B. Data from Corps of Engineers

The terrain data for the South Asian desert were obtained from the Corps of Engineers Technical Report No. 3-506 (Handbook, A Technique for Preparing Desert Terrain Analogs)[4] and a folio of plates (maps) entitled Analogs of Yuma Terrain in the South Central Asian Desert.[5]

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[4] Handbook, A Technique for Preparing Desert Terrain Analogs, TR No. 3-506, May 1959. U. S. Army Engineer Waterways Station, Corps of Engineers, Vicksburg, Miss.

[5] Analogs of Yuma Terrain in the South Central Asian Desert, (18 plates), March 1959. Geology Branch, Soils Division, U. S. Army Engineer Waterways Experiment Station, C of E, Vicksburg, Miss.

TABLE 1. DESCRIPTION OF YUMA TEST STATION VEHICLE COURSES
(See Appendix A)

	Corps of Engineers Land-Form Definition: Terrain Geometry				Soil Composition					Yuma Land-Form Definition
	Landform	Slope Occurrence	Characteristic Slope	Characteristic Relief	Type Soil	Soil Consistency	Surface Rock	Vegetation	Elevation	
A_1 Truck Level & Cross Country	4	5	3	5	6	9	0	2	2	Alluvial Hills - Desert Pavement
A_2 Truck Level & Cross Country	4	5	3	5	6	10	0	2	2	Alluvial Hills - No Definition
Hummocky Sand	7	1	1_a	1	5	1	0	2	2	Hummocky Plain - Sand
B_1 Truck Hill Course	4	5	3	5	6	10	0	2	2	Alluvial Hills - No Definition
B_2 Truck Hill Course	4	5	4	5	1	0	3_a	2	2	(Bedrock Hills) - Rocky Desert
Dynamometer Course Truck Gravel Course	1L	4	1_b	2	4	9	0	$\frac{2}{4}$	2	No other name - Gravel Course
Truck Cross Country Course	4	6	4	5	1	0	3_a	2	2	(Bedrock Hills) - Rocky Desert
Sand Dynamometer Course	7	1	1_a	1	5	1	0	2	2	Plain - Sand

TABLE 1. DESCRIPTION OF YUMA TEST STATION VEHICLE COURSES (Cont'd)

	Corps of Engineers Land-Form Definition: Terrain Geometry				Soil Composition					Yuma Land-Form Definition	
	Landform	Slope Occurrence	Characteristic Slope	Characteristic Relief	Type Soil	Soil Consistency	Surface Rock	Vegetation	Elevation		
Tank Gravel Course	1L	4	2	2	6	10	0	2	2	No Definition	- Gravel Course
C_1 Tank Level Cross Country Course	7	1	1_a	1	5	1	0	2	2	Hummocky Plain	
C_2 Tank Level Cross Country Course	1L	4	2	2	6	10	0	2	2	Alluvial Fan	
Tank Hill Course A	4	6	4	5	1	0	4	2	2	(Bedrock Hills)	- Rocky Desert
D_1 Tank Hill Course B	4	5	3	5	6	10	0	2	2	Alluvial Hill	
D_2 Tank Hill Course B	4	6	4	5	1	0	4	2	2	(Bedrock Hills)	- Rocky Desert
20%, 30%, 40% Side Slope 30%, 40%, 50% Slopes 60% Slope Sand Slopes Dust Course	1L	4	1_b	2	6	10	0	2	2	Desert Pavement	
E Vapor Lock Course NS	1L	4	1_b	2	6	10	0	2	2	Desert Pavement	

TABLE 1. DESCRIPTION OF YUMA TEST STATION VEHICLE COURSES (Cont'd)

	Corps of Engineers Land-Form Definition									Yuma Land-Form Definition
	Terrain Geometry				Soil Composition					
	Landform	Slope Occurrence	Characteristic Slope	Characteristic Relief	Type Soil	Soil Consistency	Surface Rock	Vegetation	Elevation	
E_2 Vapor Lock Course EW	4	5	4	5	6	10	0	2	2	Desert Pavement
F_1 Sand Dunes	4	5	3	4	5	1	0	2	2	Sand Dunes
F_2 Sand Dunes	4L//	4	3	5	5	1	0	2	2	Sand Dunes

The Corps of Engineers' folio, consisting of 18 plates, contained the following terrain maps:

(1) Characteristic Plan-Profile (Plate 1)

This is the most commonly found plan-profile within a region. It may be either gross or restrictive. A gross plan-profile is one that can be subdivided into two restrictive component plan-profiles each exhibiting relief of a lower order than the gross plan-profile. Random sampling with circles 35 miles in diameter is used in determining the gross plan-profile. Random sampling with circles of 1 mile in diameter is used to determine the restrictive plan-profile.

(2) Slope Occurrence (Plate 2)

This map shows the occurrence of slopes greater than 50%. Frequency of occurrence is determined in a direction containing the maximum number of slopes steeper than 50%. Minimum relief considered is 10%.

(3) Characteristic Slope (Plate 3)

Characteristic slope is defined as a narrow range of slopes, which predominates or is most common within a region (possessing a distinctive spacing, arrangement, or pattern of contour lines) mapped with a 10-foot contour interval. Slope is defined as a surface identified or designated in terms of its deviation from the horizontal. The amount of deviation is commonly expressed as a rate of vertical rise per horizontal interval, as a percentage, or in degree.

(4) Characteristic Relief (Plate 4)

Where the characteristic slope is less than 6 degrees (approximately 10%) relief is defined as the vertical distance from interfluve crest to the immediately adjacent flow line. In those areas where the characteristic slope is greater than 6 degrees, relief is defined as the maximum difference in elevation per square mile, or in areas where drainage lines are poorly developed or lacking (sand dune areas), from summit to adjacent low.

(5) Generalized Landscape (Plate 5)

This plate is a composite map of the landform types found under the major landscape features of mountains, plains, hill lands, plateaus.

(6) Soil Type (Plate 6)

This map deals with soil-rock associations; areas characterized by a mosiac of bare rock and stony soils with varying degrees of scattered patches of coarse and fine-grained soils.

(a) stony soils - More than 75% of a typical sample consists of material coarser than gravel.

(b) coarse grained soils - More than 50% of a typical sample consists of sand and/or gravel.

(c) fine-grained soils - More than 50% of a typical sample consists of silt and/or clay.

(7) Soil Consistency (Plate 7)

This map presents the conditions of soils as follows:

(a) Homogeneous consistencies: Soils of essentially unchanged consistencies to depths greater than 18 inches.

(i) Noncohesive: Materials in which the constituent particles do not adhere to each other

(ii) Cohesive: Materials in which the constituent particles do adhere to each other, either because of mutual attraction of the particles themselves, or because of the presence of a cementing material.

(b) Layered consistencies: Soils having two or more relatively discrete layers within 18 inches of the surface.

(i) Cohesive surface layer underlain by either softer cohesive materials, or by noncohesive materials.

(ii) Noncohesive surface layer underlain by either looser or denser noncohesive materials, or by cohesive materials.

(8) Surface Rock (Plate 8)

This map includes the regions where rock is exposed and at shallow depths (i. e., 0-10 ft). Types of rock designated include:

(a) Igneous (Undifferentiated): Rocks found by solidification or crystallization of a hot fluid mass (i. e., granite, syenite, diorite, basalt.)

(b) Metamorphic (Undifferentiated): Rocks formed from original igneous or sedimentary rocks through alterations produced by pressure, heat, or the infiltration of other materials at depths below the surface zones of weathering or cementing. (i. e., gneiss, schist, slate)

(c) Sedimentary (Undifferentiated): Rocks formed from material laid down in a more or less finely divided state, as sediment, through the agency of water, wind or glaciers (i. e., sandstone, limestone, shale).

(9) Vegetation (Plate 9)

This plate is a map of the vegetation types and includes the following units: barren, sparse shrub and grass, scattered shrub and grass, scrubby trees, dense shrub and/or scrubby trees, palms with or without grain-herb cultivation, steppe, steppe-savanna, grain-herb cultivation, marsh.

(10) Geometry or Form (Plate 10)

This plate identifies landscape type as a combination of

(a) characteristic plan-profile
(b) slope occurrence
(c) slope
(d) relief

(11) Ground (Plate 11)

Soil type and surface rock or soil consistency are considered in this composite map. Much of the South Central Asian desert is highly analogous to the Yuma terrain.

(12) Vegetation Analogs (Plate 12)

(13) Composite Analogs (Plate 13)

This analog superposes geometry, ground and vegetation mapping components.

(14) Physiography (Plate 14)

This analog shows the mountains, plain and mountains complex, hill lands, plateaus, and plains.

(15) Physiography - Descriptions and Photographs (Plates 15 & 15A)

(16) Hypsometry (Plate 16)

Land form elevations are shown in the range of from below sea level to 15,000 ft above sea level.

(17) Landform-Surface Conditions (Plate 17)

An analog of landform and surface conditions

(a) Depositional (alluvial, colluvial, lacustrine, eolian, marine, organic-chemical)

(b) Erosional (surface water, wind, marine)

(c) Miscellaneous (volcanic, tectonic, residual, intrusive, meteoric)

(18) Landform-Surface Conditions (Plates 18, 18A & 18B)

Descriptions and photographs of landform and surface conditions.

C. Technique of Making Plots

As mentioned, the first effort was directed toward establishing the Yuma test course terrain definition in terms consistent with those plotted on the Corps of Engineers maps. (See Table 1). Next, the terminology used at the Yuma Test Center was listed, and efforts were made to correlate the various terms with the sets of numbers selected from the maps. General agreement was found to exist in the terminology, although the descriptive terms were not always similar. Terms were found to apply to combinations

of soil conditions, while others applied to terrain configurations. For instance, the term "hummocky," which is used to describe terrain condition at Yuma, does not appear in the Corps of Engineers terminology.

The correlation of Yuma test course data in a direct translation to the conditions existing in Asia was investigated and found to have limited possibility. The limiting factor was the lack of precise overlap of terrain-data definitions. To offset this disadvantage, Yuma data were generalized and subjectively rearranged to conform to the Asian desert terrain descriptions.

Some of the terrain features were found to be directly related to the occurrence of climatic factors, and thus required the addition of climatic data to the set of conditions to be plotted. This compounding of terrain and climatic features will be discussed later.

The basic plots of mobility data were based on those areas in which difficulties were known to occur. This constituted a negative type of plot; however, since engineering work is generally concerned with problem areas rather than areas which are normally successful, this type of plot more closely followed engineering procedure.

The unplotted areas were divided into two basic categories:

(1) those areas in which performance was not known, and
(2) those areas in which performance was known to be satisfactory.

Next the reports of desert evaluations conducted on the vehicles were given definitive examination and review. This review included a careful analysis of all statements, data, and observations relating to mobility-terrain performance results. (See Appendix B for summaries of the vehicle performance capabilities.)

The Envanal charts were then examined to determine the reliability of utilizing these documents for obtaining mobility-terrain relationships, rather than referring to the test report itself. In the reports examined, the Envanal charts generally were adequate representations of the test results, for the purposes of preparing the analogs. On some occasions, slight amplification of the Envanal charts was desired, but the questions were of minor magnitudes.

Two types of limitations were used for plotting: a lower upper-limit, and a higher upper-limit. The lower upper-limit indicated the point at which any specification would be exceeded, whereas, the higher upper-limit was the point at which further operation would destroy or severely damage the

equipment, or imperil the operation, and usually meant that the specification was substantially exceeded or that several specifications were exceeded simultaneously.

The limits and the reasons for the limits are thus evaluated in terms of various sets of conditions which, when occurring, would produce a situation of poor performance.

In general terms, terrain is a relatively fixed factor varying only with location, whereas climatic factors will vary from day-to-day for a fixed location, in addition to varying with location. Thus, if position or location is fixed, the climatic factor will vary from day-to-day, while the terrain feature will remain constant.

In some instances, certain features of the terrain may be a redundant part of the plotting procedure; however, it is still presented as being a definitely known contributing factor to the problem. An example of this type is the plotting of sand dunes on the terrain map for the XM274 vehicle. The existence of the sand dunes is not the problem, but becomes a problem in conjunction with the occurrence of a 100°F temperature. Such an area could be plotted as a function of the occurrence of 100°F temperature without plotting sand dunes; however, in this study,the area is plotted as an area of sand dunes, which may or may not be negotiable, depending upon the temperature.

The terrain maps contain areas which are mapped as mixed groups; therefore, it becomes necessary to map performance as mixed groups. Thus, areas were established which were generally considered as "definitely not advisable to operate in," and other areas in which the vehicle "can be operated in." In certain cases,the information required to make a definite decision was not available. These mixed areas often contain a portion of the terrain that is definitely known to be unfavorable, while at the same time they also contain areas that are favorable for operation. Since these areas could not be isolated, it was generally stated that the area is "selective," or actually contains some of both conditions. Wherever these mixed areas exist,they will have to be defined either by more definitive plotting of basic terrain data within the area, or the user of the maps will have to interpret the maps accordingly.

The vehicle performance analogs compiled for this study show three conditions based on available atmospheric and terrain data. The three conditions are defined as.

(1) "Go" -- A "go" condition exists for the vehicle within an area if all sets of limitations listed under selection of criteria are <u>not</u> met.

(2) "May Go" -- A "may go" condition would exist, for example, when terrain limitations are not met, but certain atmospheric limits are met; or terrain or atmospheric data are not substantiated or are questionable as to their veracity. A "may go" condition is shown as either "selective" or "doubtful." Examples of such situations are as follows:

(a) Selective -- An area contains both "go" and "no-go" criteria as listed for the vehicle.

(b) Doubtful -- An area where no clear indication "no-go" criteria exists, but subjective deduction indicates the existence of such criteria.

(3) "No-Go" -- A "no-go" condition exists if any sets of limits listed under selection criteria are met.

Of the 18 terrain plates on the South Asian desert, only two proved to be of consequence to the study. They were Plate 5 (Generalized Landscape) and Plate 16 (Hypsometry).

The first of these (Plate 5) was a combination presentation of: Landform (Plate 1), Slope Occurrence (Plate 2), Characteristic Slope (Plate 3), and Characteristic Relief (Plate 4). Within this group, it was soon discovered that the characteristic slope map predominated in describing vehicle limitations. The reason was that the test reports, themselves, only contained information in this respect. Limitations imposed by the other landforms were seldom, if ever, correlated with test data, and could only be used selectively.

The hypsometry plate proved of value in drawing the temperature frequency lines. Since temperature is generally a function of elevation (hypsometry), the plate was used for interpolation of isotherm direction.

D. Preparation of the Mobility-Terrain Maps

As mentioned, the plotting was done on a negative-type basis; that is, those areas where "No-Go" conditions existed were first plotted, then the ones designated as "Selective" or "Doubtful" were plotted; and the remainder was considered as "Go." Therefore, all criteria were expressed in terms of the vehicles limitations.

1. <u>The Selective Criteria Were Firmly Established</u>

The first step was to select the appropriate criteria which would delineate between the various mobility-terrain relationships (that is: "No-Go, " "Doubtful, " Selective, " or "Go".) These criteria were then related to the various terrain analogs.

a. <u>"No-Go" Plot</u>

Using the M35 truck as an example, the critical performance point for "No-Go" mobility-terrain relationships was the 50% slope. Therefore, the occurrence of any of the following sets of landform conditions constituted an area in which the "No-Go" plot was made.

PP*	SO*	CS*	CR*
4	5	5	5
4	5	5	6
4	6	5	5
4	6	5	6
4	6	5	7
4L	5	5	5
4L//	6	5	6
4L//	6	5	7

*PP -- Plan Profile SO -- Slope Occurrence
CS -- Characteristic Slope CR -- Characteristic Relief

Generally, the four above landform conditions were used exclusively in defining "No-Go" limitations. On occasion, however, additional landform aspects were considered. For example, in the case of the M35 truck, it was noted in the reports that the vehicle had difficulty in operating for sustained periods in sand dune operations. Therefore, those landform characteristics necessary to define sand dune conditions were used, resulting in the addition of soil characteristic to the sets of conditions. The following tabulation shows the sets that were brought into play to further define "No-Go" aspects for the M35 truck, as a result of this inability to operate in sand dunes.

PP	SO	CS	CR	SC
5L//	4	3	5	5
6L//	3	3	5	5
6L	3	3	5	5
6	2	3	4	5
6	3	3	4	5
6	4	3	4	5

PP -- Plan Profile SO -- Slope Occurrence CS -- Characteristic Slope
CR -- Characteristic SC -- Soil Characteristics

Finally, a unique condition could occur where only a single parameter was needed to evaluate the "No-Go" quality of the vehicle. Again, using the M35 truck as an example, indications were that the presence of a soil with a "3" classification on the Corps of Engineers soil consistency analog would result in vehicle immobilization (a "3" classification denoted a soft soil with little or no bearing capacity.) Thus, any time the "3" condition existed, regardless of the other landform qualities, a "No-Go" plot occurred.

b. <u>"Doubtful" Plots</u>

The "Doubtful" plot was utilized when there was no clear indication of nonmobility, but subjective reasoning indicated that the vehicle would probably be inoperable.

For example, in the case of the M35 truck, test results indicated that under certain conditions the vehicle would not negotiate a 20% slope. Under ideal conditions it would negotiate a 50% slope. Thus, any time a slope condition occurred that was equal to or greater than 20% but less than 50%, a "Doubtful" plot was followed. The landform combinations that indicated this situation were:

PP	SO	CS	CR
4	5	4	5
4	6	4	5

PP -- Plan Profile CS -- Characteristic Slope
SO -- Slope Occurrence CR -- Characteristic Relief

Occasionally there were single parameters that would exist in which subjective reasoning would cause doubt as to the vehicle's operability, but in which no precise limitations were known. Again, using the M35 truck as an example, a "Doubtful" plot occurred when a soil consistency rating of "6" (hard, thin crust overlying soft materials, commonly muck, ooze, saturated silts) existed.

c. "Selective"

"Selective" plot was utilized whenever an areal complex occurred, and one of these complexes was a "No-Go" type of terrain feature or combination.

d. "Go" Plot

The "Go" plot was placed in all areas which did not fall within the preceding catagories.

IV. TESTING OF RESULTS ON VEHICLES BY ANALOGS

Preceding chapters have discussed the approach taken in establishing the terrain analogs and the atmospheric analogs. The purpose of this chapter is to apply these approaches to actual plotting of the analogs for four vehicles: Tank, 90mm Gun, M48; Carrier, Light weapons, Infantry, 4 × 4, M274; Truck, Cargo, Prime Mover, 2-1/2-Ton, 6 × 6 M35; and Carrier, Personnel, Fulltracked, M113.

Summaries of the reports from which test results were obtained are in Appendix C.

A. Tank, 90mm Gun, M48

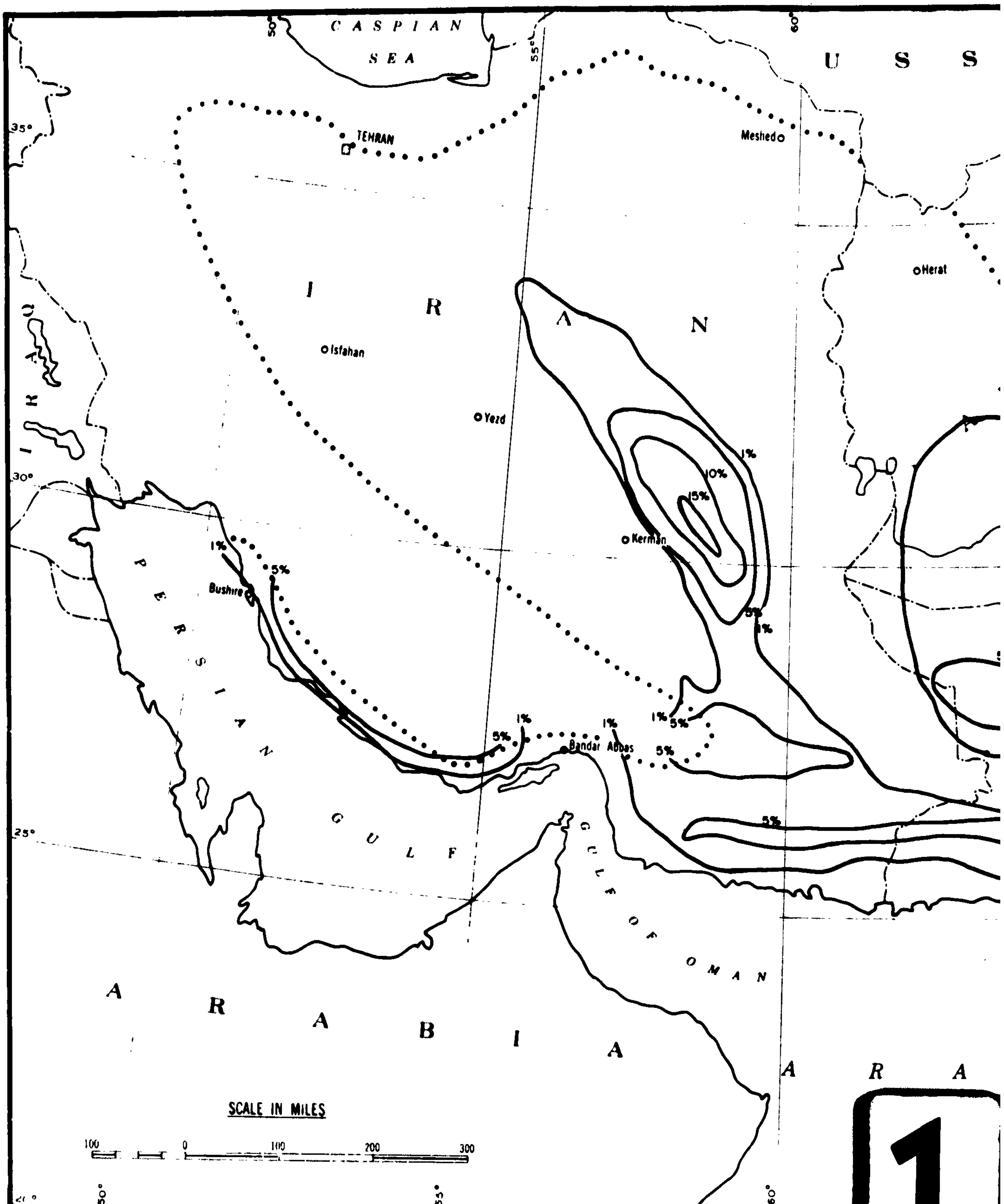
This vehicle was found to have vapor locking tendencies which would occur at temperatures of 100°F. Engine cooling problems would occur at 113°F. Since the vapor locking tendency was not serious at the 100°F temperature, the 113°F temperature level was selected as the lower temperature limit. The upper temperature limit of 125°F was established as the highest possible temperature operating level because of rate of temperature rise in vehicle components. The cylinder heads on the main engine will overheat at full-load, main engine oil temperatures will be borderline, and serious vapor lock will occur.

Figure 3A plots the probability of occurrence for temperatures equaling or exceeding 113°F during the warmest month in the South Asian Desert. This, then, is an estimate for percentage of time that temperatures would cause the M48 tank's component temperatures to exceed the design specifications under selected operating conditions.

Figure 3B plots the probability of occurrence for temperatures equaling or exceeding 125°F during the warmest month. This would then be an estimate of percentage of time that any operation would be hazardous in the designated areas, because of high temperature.

Test performance reports revealed that the maximum slope climbing ability of the M48 tank was 40 percent. The Corp of Engineers' terrain maps did not plot 40 percent slopes, but did plot slopes in the range from 25 to 50 percent. Thus, the actual "No-Go" terrain plot includes 50 percent and greater slopes, which are actually ten percent above the maximum limit of the vehicle. This is not the ideal manner in which to make a plot; however, in this case, it represents the most accurate plot based on

FIGURE 3A. PROBABILITY OF OCCURRENCE TEMPE
(LOWER MAXIMUM TEMPERATURE LIMIT)



BILITY OF OCCURRENCE TEMPERATURES ≥ 113°F, WARMEST MONTH
MAXIMUM TEMPERATURE LIMIT) (TANK, 90MM GUN, M48)

2

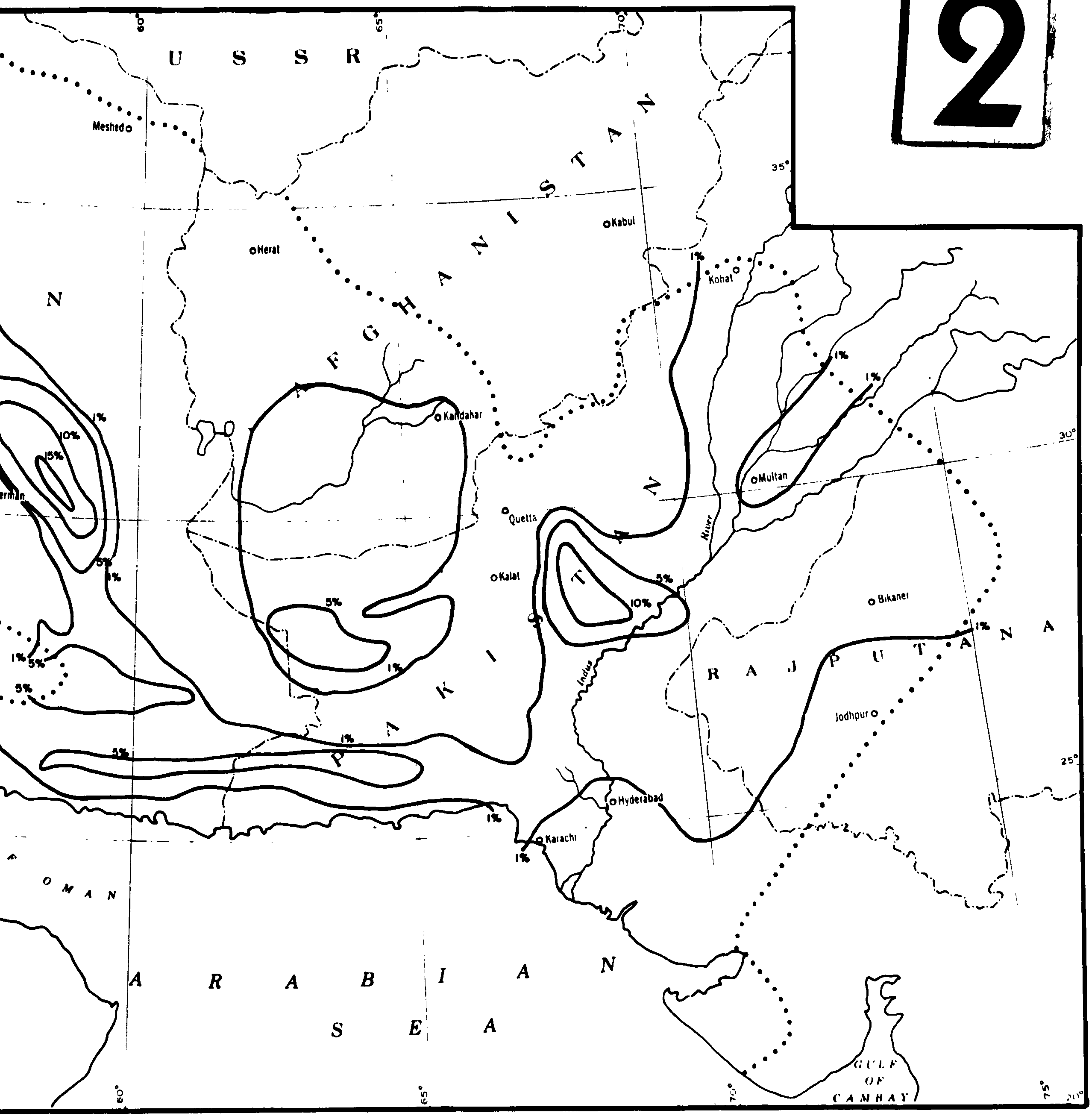
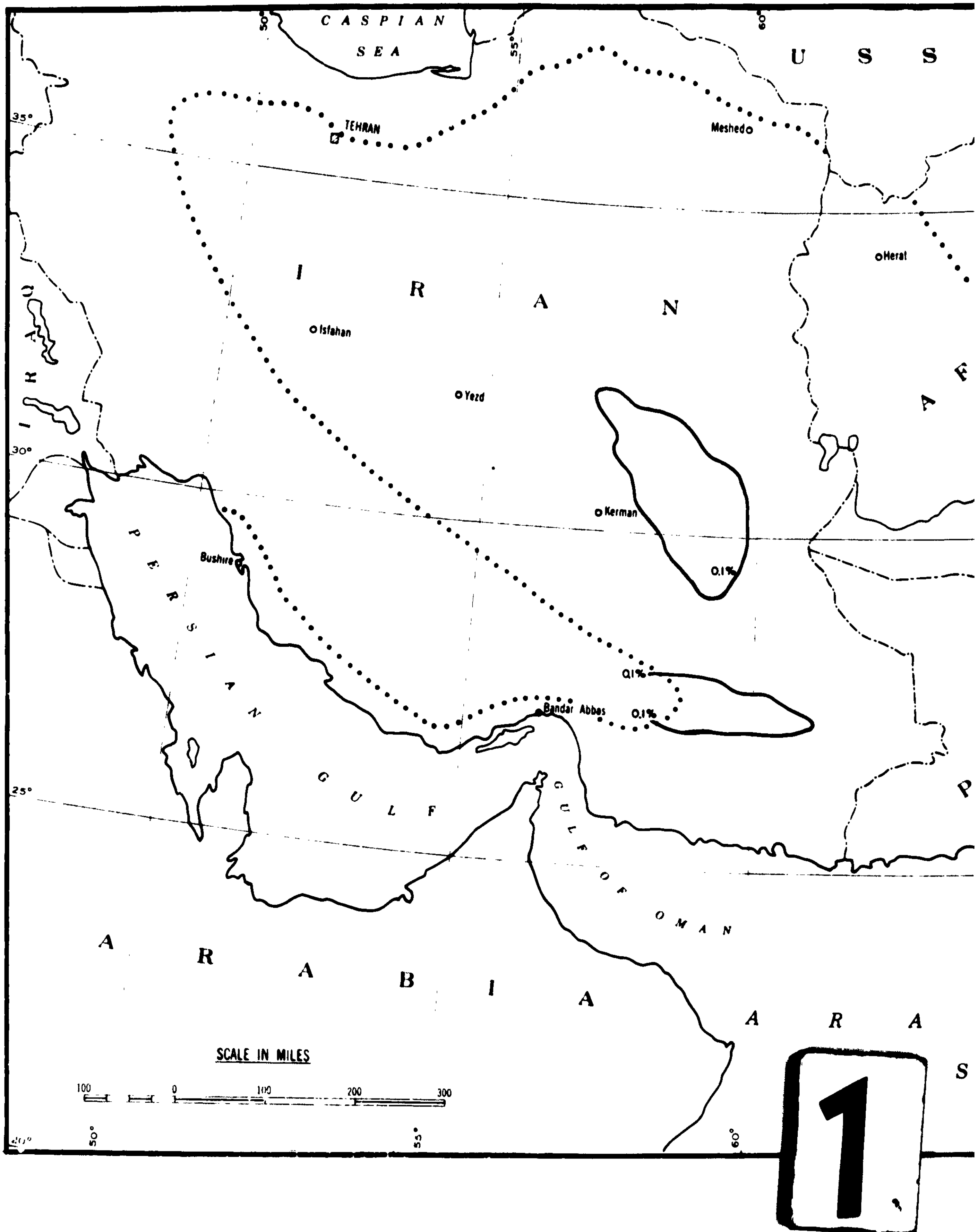
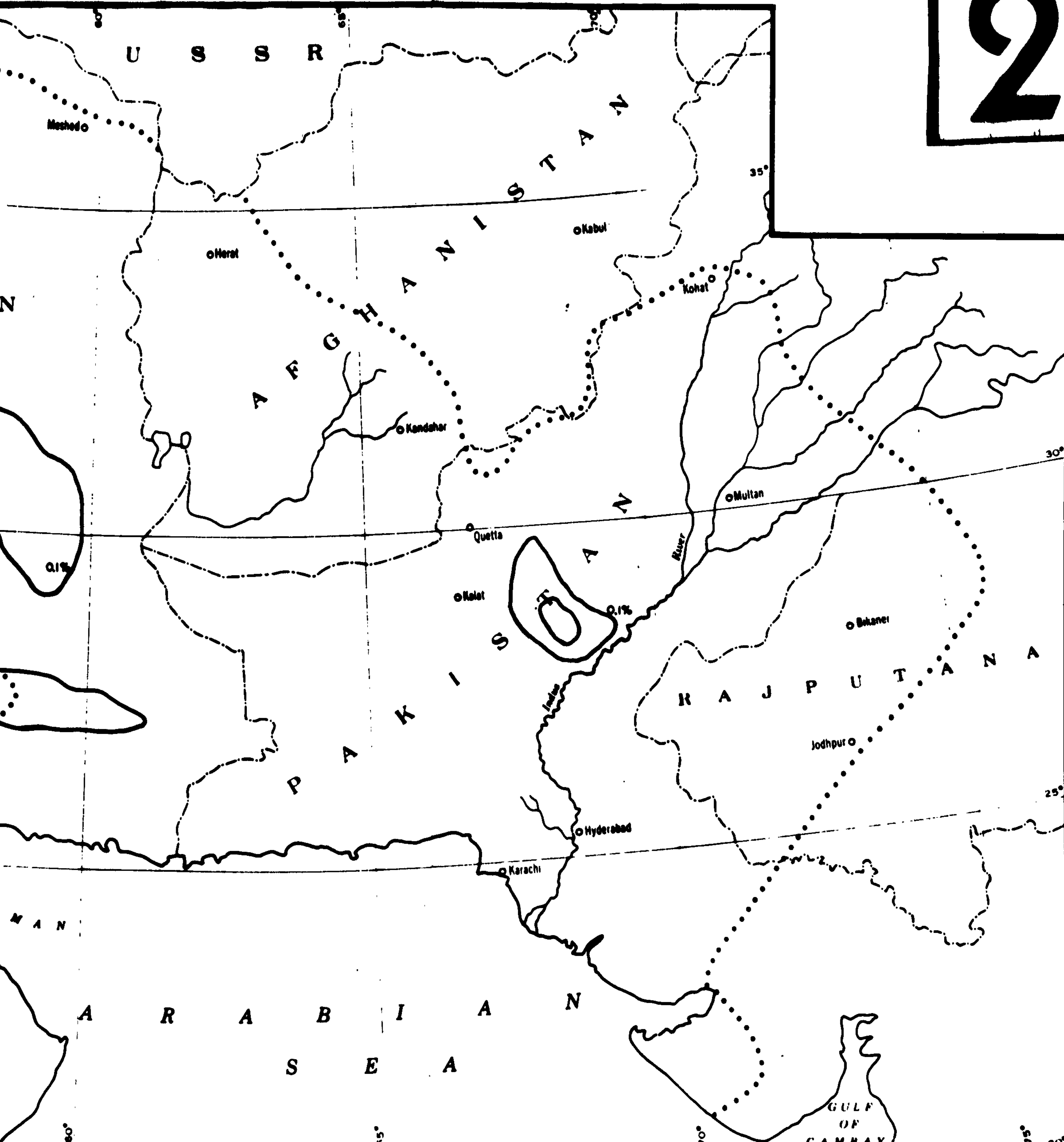


FIGURE 3B. PROBABILITY OF OCCURRENCE TEMPERA
(UPPER MAXIMUM TEMPERATURE LIMIT) (TA



TY OF OCCURRENCE TEMPERATURES ≧ 125°F, WARMEST MONTH
IMUM TEMPERATURE LIMIT) (TANK, 90MM GUN, M48)

2



availability of existing data pertaining to the terrain and the breakdown of plotting categories.

There are some areas plotted on the map which represent personal injection of interpretation on the part of the authors and were not obtained from reports of any type. These areas include marshlands, perennial wet soils, and soils underlain with soft materials. In these areas,the condition of "Doubtful" or "Selective" negotiability was expressed.

Figure 3C plots the mobility-terrain relationship for the vehicle.

The selection criteria for "No-Go" operation were established for a characteristic slope equal to or greater than 50%, and also when a soil characteristic of "3" (as defined in the Corp of Engineers Mapping Code found in the Appendix) existed. Therefore, the following generalized landform codings were used to define "No-Go":

PP	SO	CS	CR	SC
1	3	5	4	-
4	5	5	5	-
4	5	5	6	-
4	6	5	5	-
4	6	5	6	-
4	6	5	7	-
4 L//	6	5	6	-
4 L//	4	5	5	-
5 L//	4	5	5	-
Any	Any	Any	Any	3

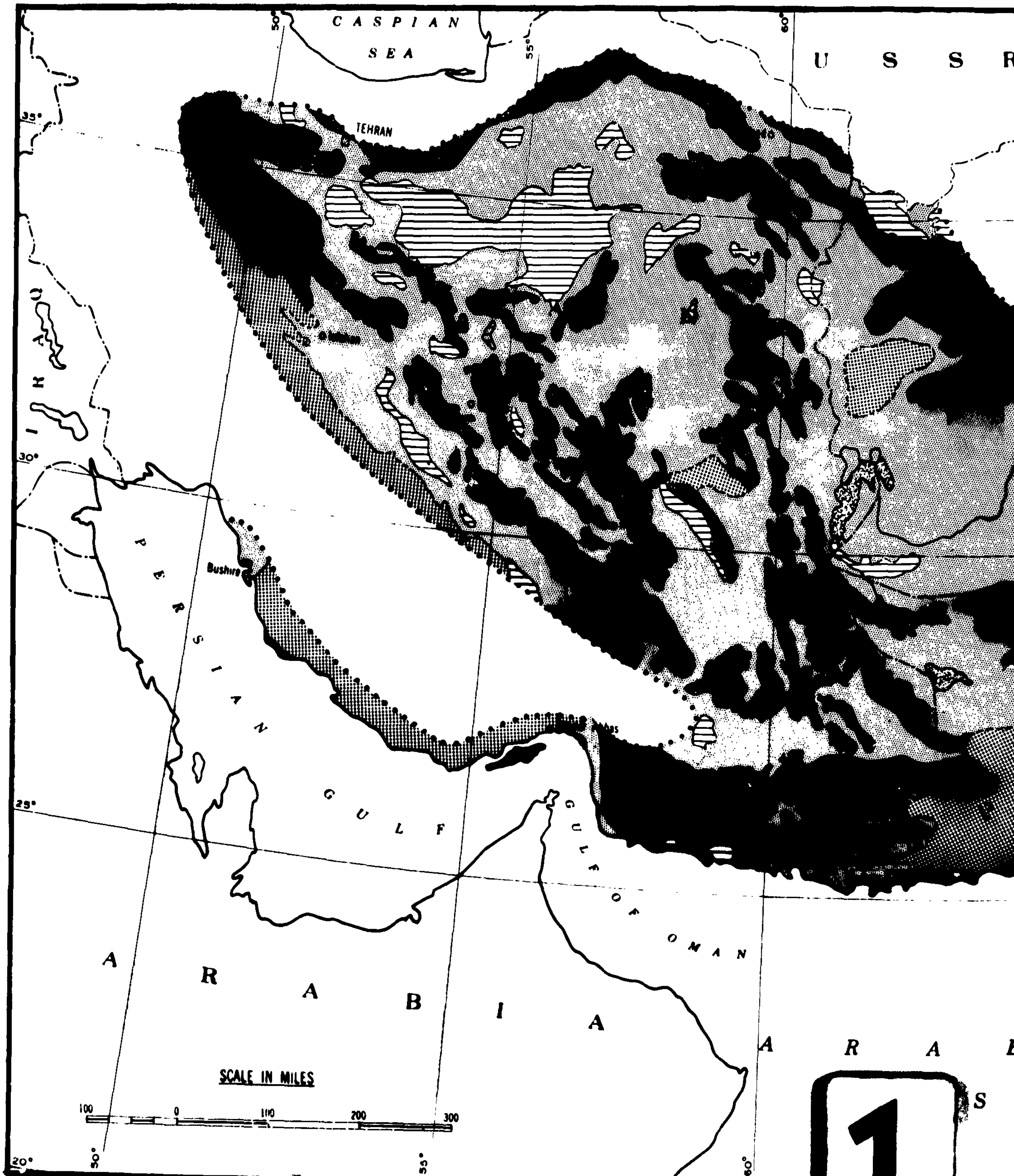
A "Doubtful" plot occurred whenever Code "6" (hard thin crust overlying soft materials, etc.) existed in the Corps of Engineers Soil Consistency Analog.

And finally, a "Selective" condition existed when some areal complex occurred in which a "No-Go" condition, as shown above, existed.

B. <u>Carrier, Light Weapons, Infantry, 4 × 4, M274</u>

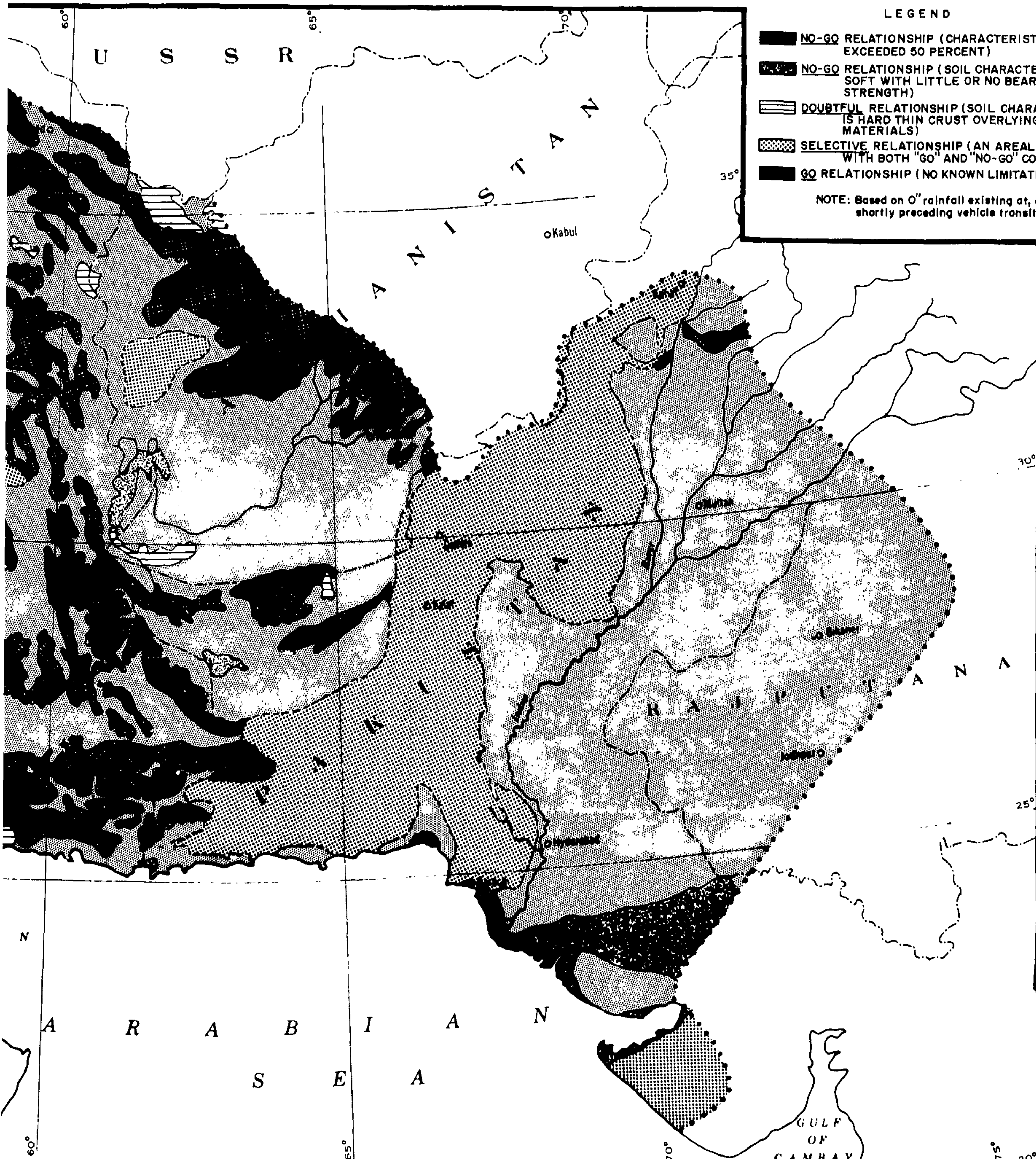
The M274 Infantry vehicle's engine temperatures exceeded specifications when operating under full-load conditions at 82°F ambient. In an ambient of 100°F, the condition would become severe enough to completely immobilize the vehicle.

FIGURE 3C. MOBILITY-TERRAIN REL
(TANK, 90MM GUN, M48)



1

3C. MOBILITY-TERRAIN RELATIONSHIP (TANK, 90MM GUN, M48)



2

Figure 4A plots the probability of occurrence for temperatures equaling or exceeding 82°F in the South Asian desert during the warmest month. This, then, is an estimate of the percentage of time that temperatures will occur during this month which would cause the M274 vehicle's component temperatures to exceed design specifications under certain operating conditions.

Figure 4B plots the probability of occurrence for temperatures equaling or exceeding 100°F during the warmest month. This would be an estimate of the percentage of time for the month that any operation would be hazardous in the designated areas because of high ambient temperatures.

The carrier M274 was found to have a maximum slope-climbing ability of 60%. Here again, the nearest Corps of Engineers' plot of terrain was 50%. Thus, the plot of unsatisfactory area includes slopes 10% under that which the vehicle will climb.

"No-Go" conditions occurred under the following Code situations:

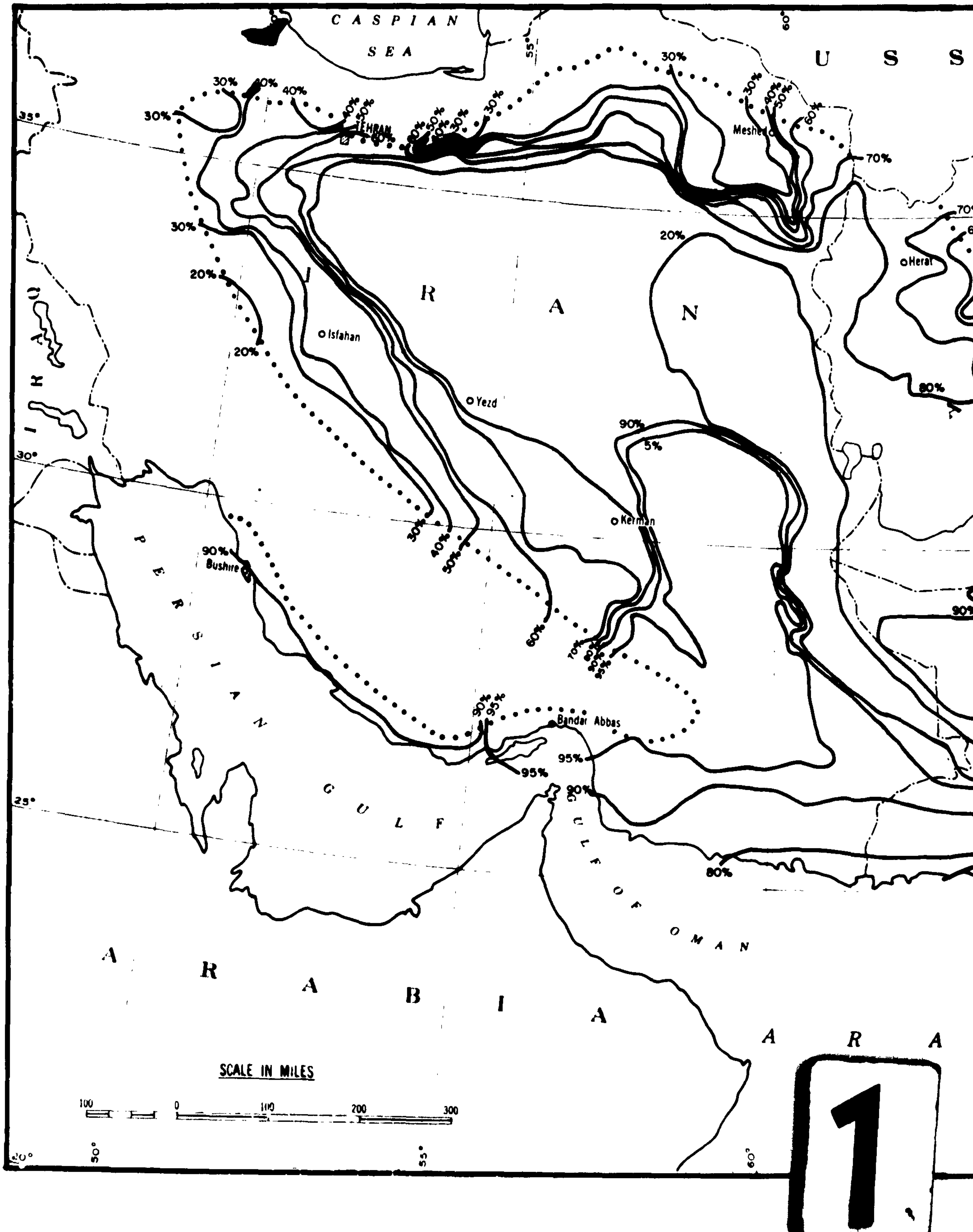
PP	SO	CS	CR
1	3	5	4
4	5	5	5
4	5	5	6
4	6	5	5
4	6	5	6
4	6	5	7
4L//	6	5	6
4L//	6	5	7
4L//	4	5	5

A "No-Go" plot was also followed whenever the soil condition was equal to the Corps of Engineers Classification of "3" (see Appendix A for precise definition.) A "Doubtful" plot was used whenever the soil consistency was equal to a "6" (see Corps of Engineers Coding Description in the Appendix A for precise definition.)

And finally, "Selective" plot was used when areal complexes existed which contained some of "No-Go" conditions as defined above, in combination with "Go" conditions.

The mobility-terrain relationships are plotted in Figure 4C.

FIGURE 4A. PROBABILITY OF OCCURRENCE TEMPERATU
(LOWER MAXIMUM TEMPERATURE LIMIT) (CARRI



CURRENCE TEMPERATURES ≥ 82°F, WARMEST MONTH
MPERATURE LIMIT) (CARRIER LIGHT WEAPONS, INFANTRY, 4 x 4, M274)

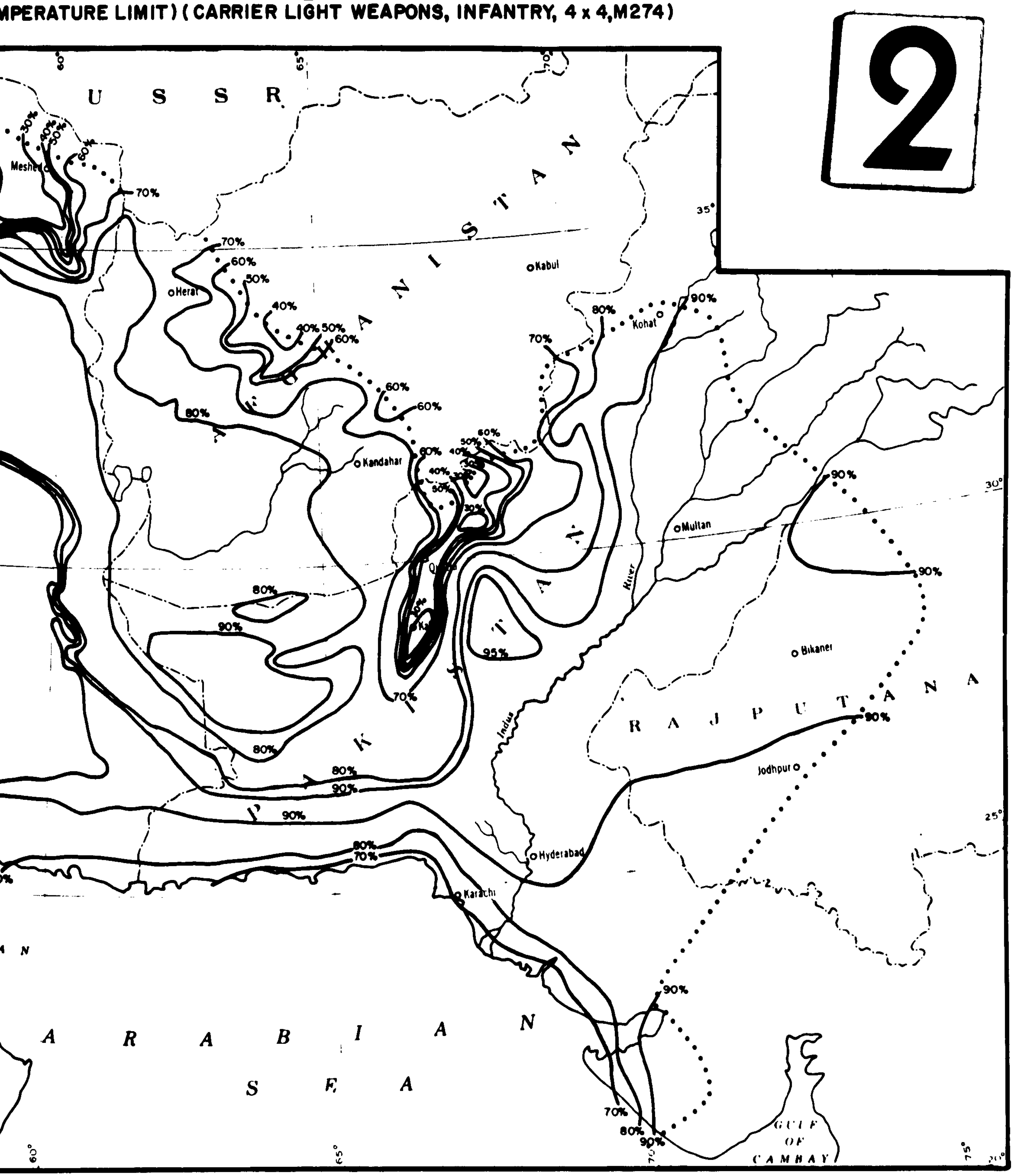
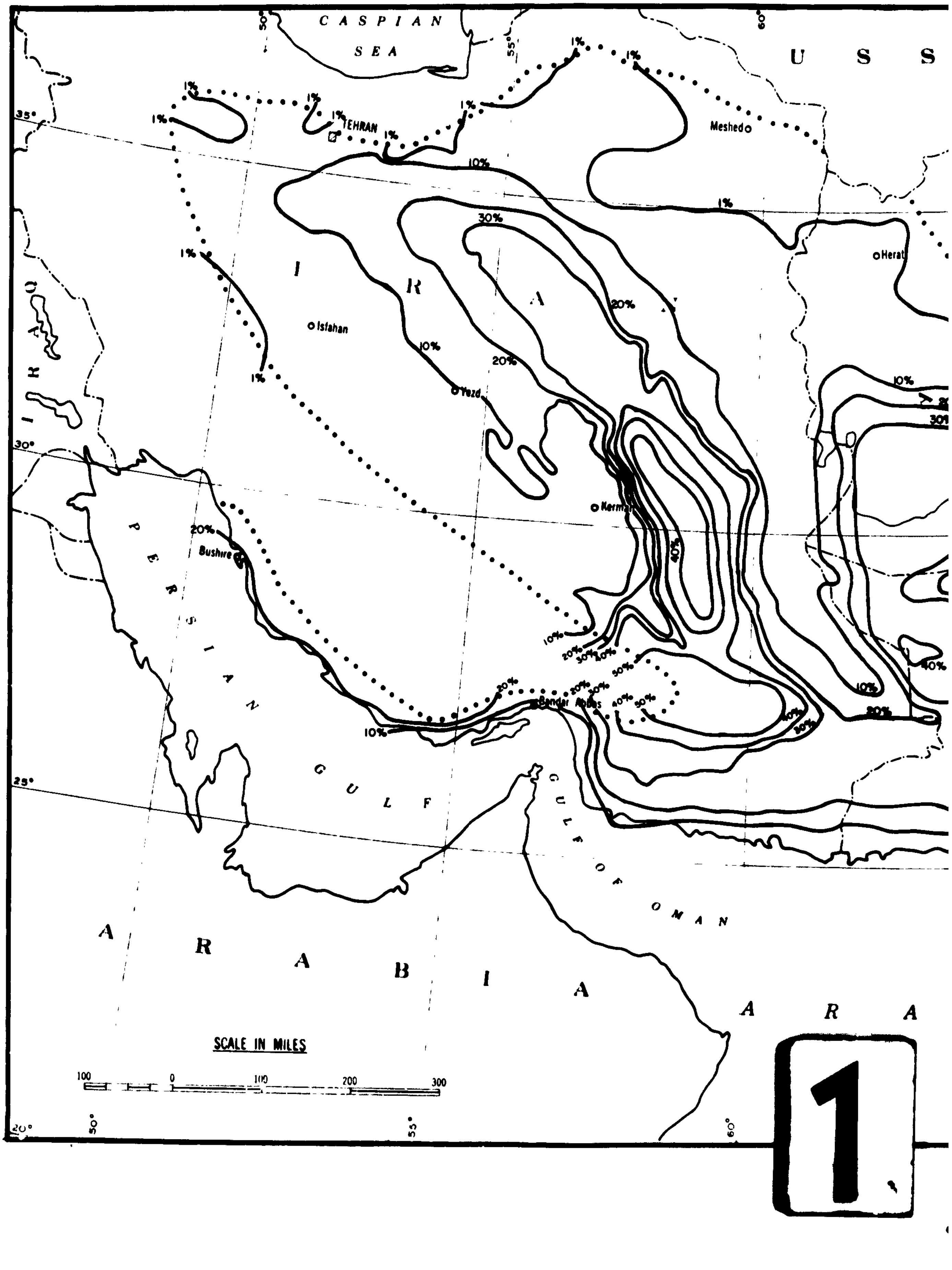


FIGURE 4B. PROBABILITY OF OCCURRENCE TEMPERAT
(UPPER MAXIMUM TEMPERATURE LIMIT) (CARR



ITY OF OCCURRENCE TEMPERATURES ≥ 100°F, WARMEST MONTH
XIMUM TEMPERATURE LIMIT) (CARRIER, LIGHT WEAPONS, INFANTRY, 4 x 4, M274)

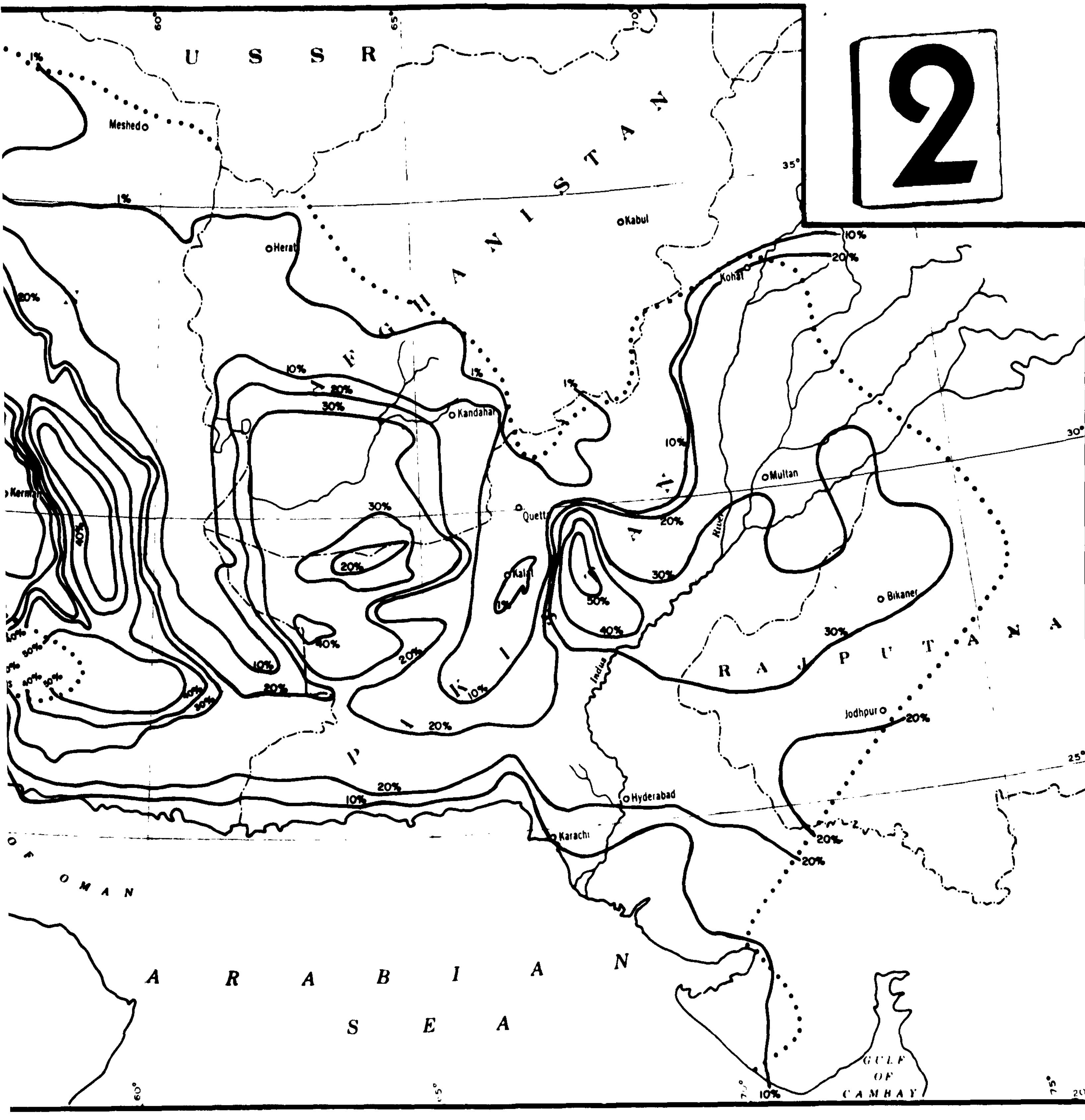
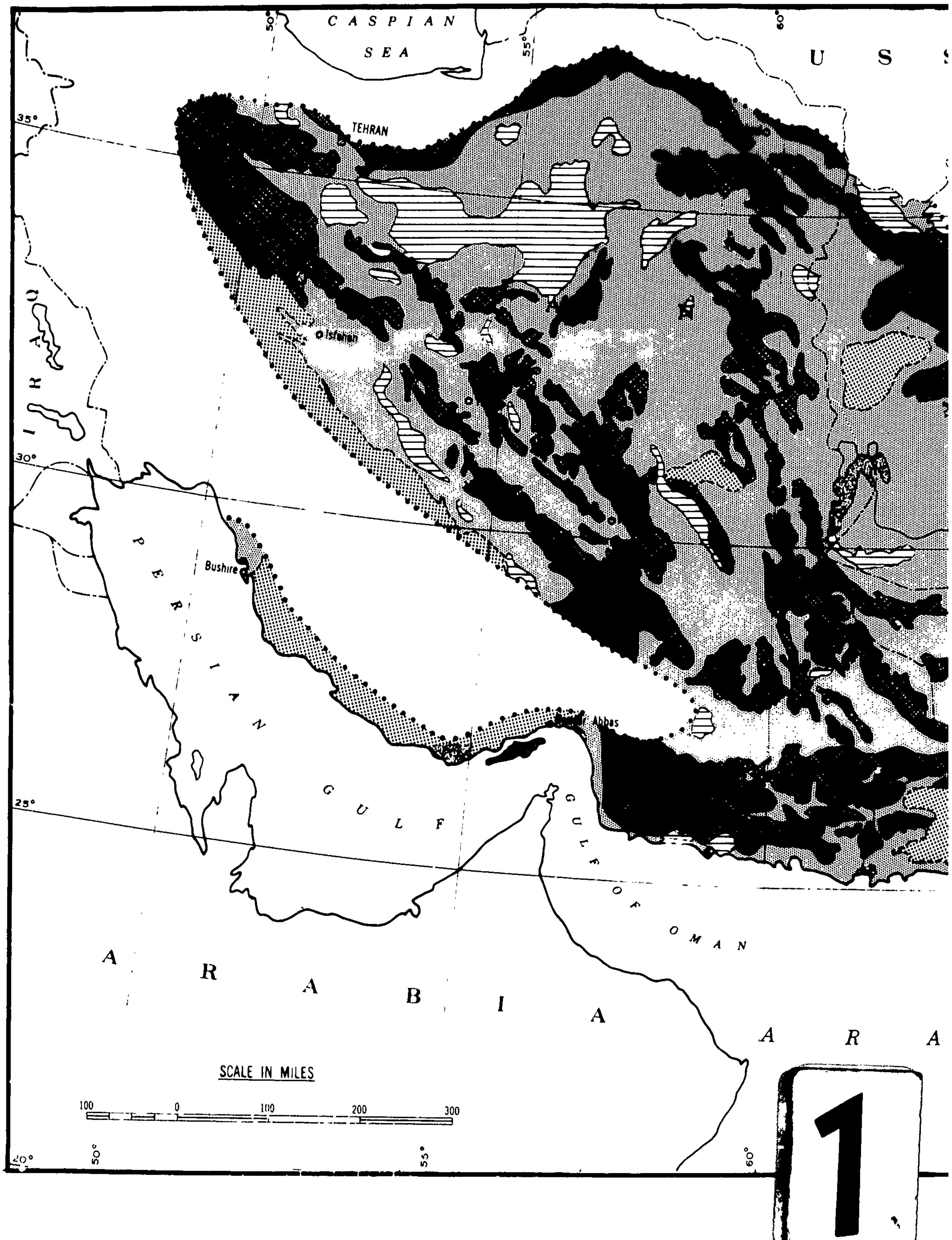
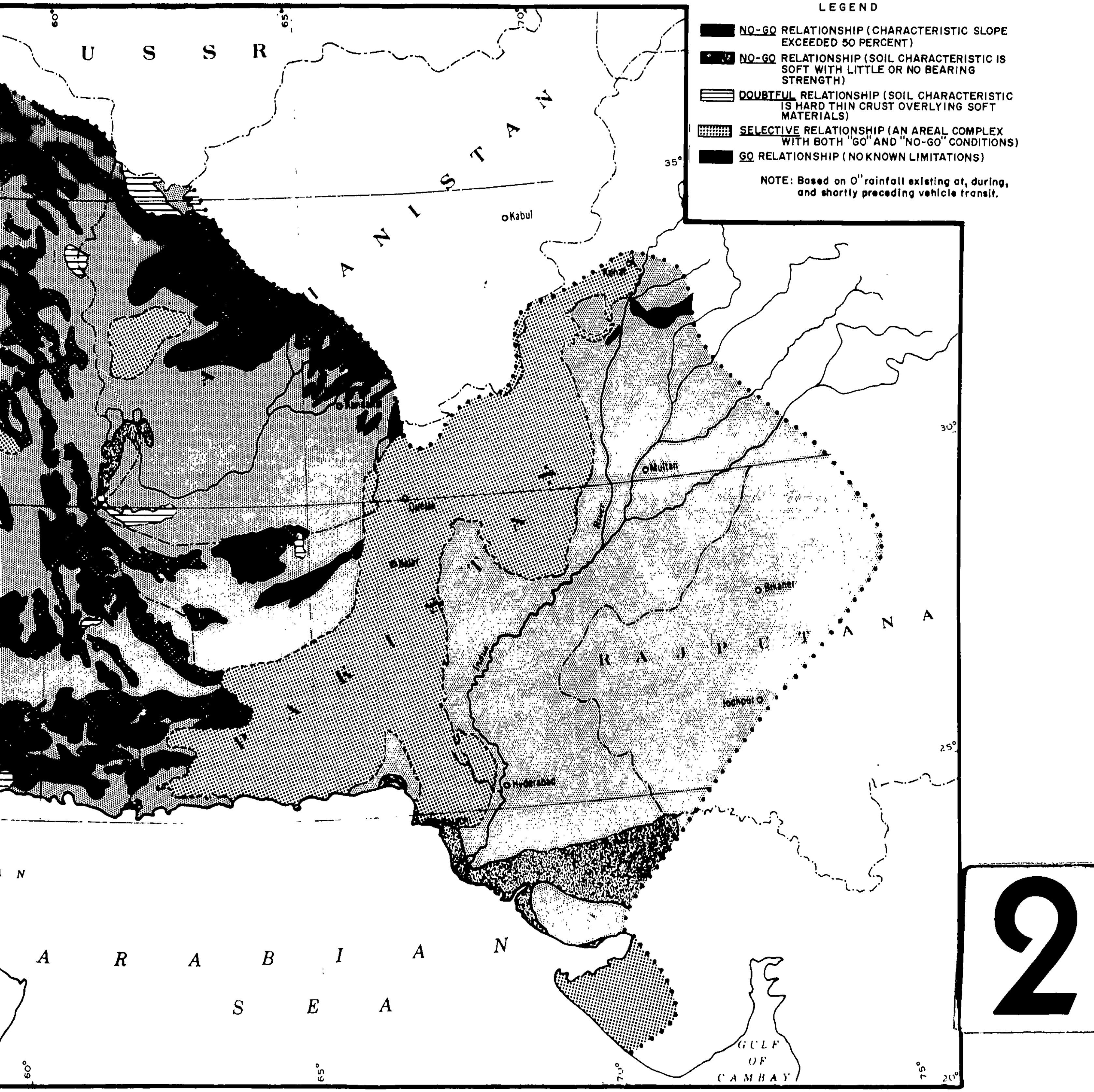


FIGURE 4C. MOBILITY-TERRAIN F
(CARRIER, LIGHT WEAPO



-OBILITY-TERRAIN RELATIONSHIP
CARRIER, LIGHT WEAPONS, INFANTRY, 4x4, M274)



C. Truck, Cargo, Prime Mover, 2-1/2 Ton, 6 × 6, M35

The lower temperature limit for the M35 truck was found to be 103°F; the upper limit was 125°F. The problems of vapor lock and engine cooling were the primary temperature dependent malfunctions which occurred during the testing operations. Tests were made using a submerged fuel pump, oil cooler, and 6-blade cooling fan; however, verbal field reports indicate that these items have not been authorized to date as standard vehicle modifications for field use.

Figure 5A plots the probability of occurrence for temperatures equaling or exceeding 103° F during the warmest month in the South Asian Desert. Again, this is an estimate of the percentage of time for the month that temperatures will occur which would cause the M35 truck's compartment temperatures to exceed design specifications under certain operating conditions.

Figure 5B indicates the probability of occurrence for temperatures equaling or exceeding 125°F during the warmest month. This would then be an estimate of the percentage of time for the month that any operation would be hazardous in the designated areas because of high ambient temperatures.

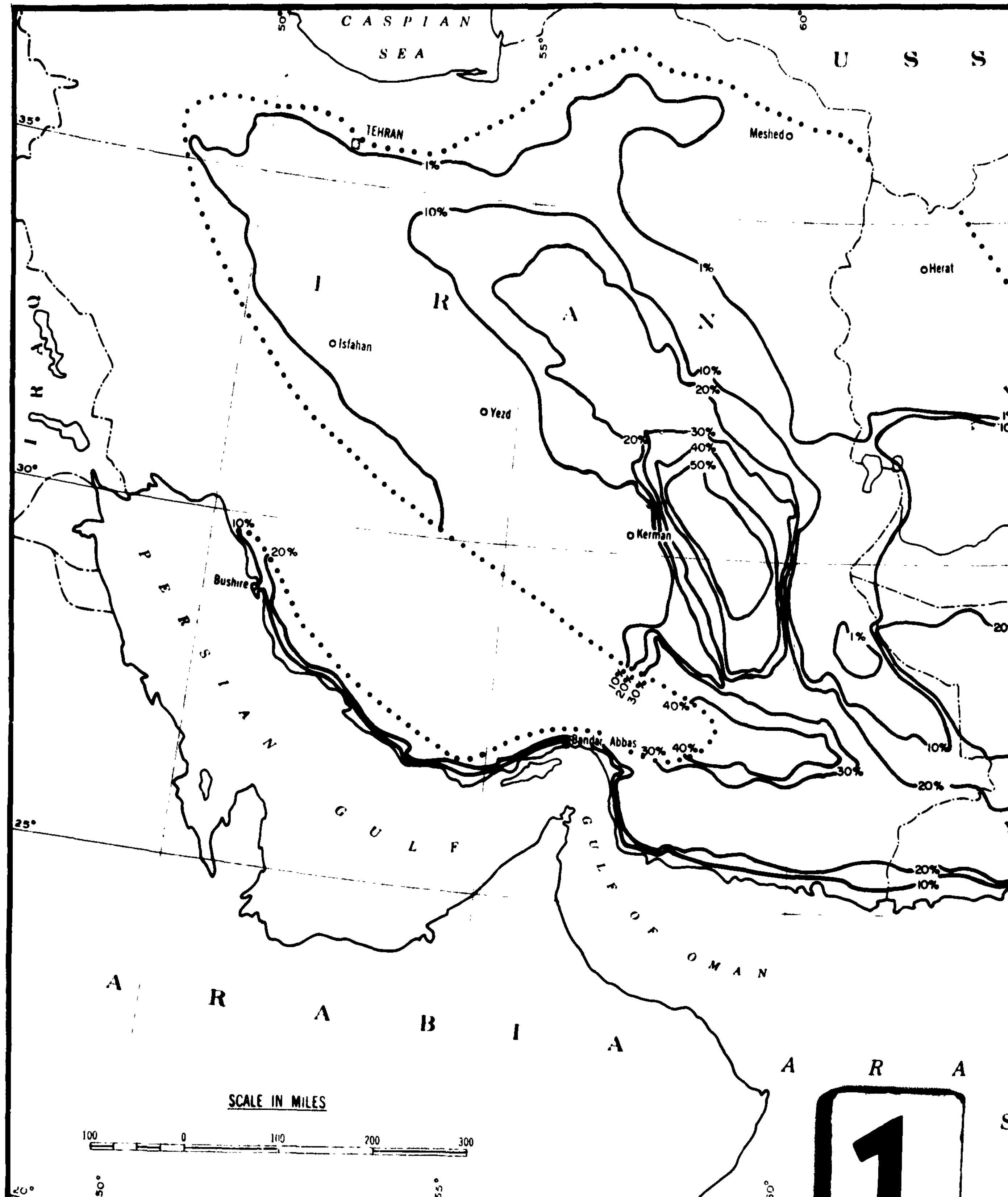
The M35 truck was generally confined to a maximum sand slope of 20 percent. No other definitive relationships were given which would relate maximum gradability to type of terrain. Therefore, the slope of maximum negotiability was selected as 25 percent to coincide with an existing analog plot.

The selection of criteria for the M35 vehicle was established as follows for a "No-Go" plot:

PP	SO	CS	CR
4	5	5	5
4	5	5	6
4	6	5	5
4	6	5	6
4	6	5	7
4 L//	5	5	5
4 L//	6	5	6
4 L//	6	5	7

Because of the inability of the vehicle to negotiate sand dunes satisfactorily, an additional limitation had to be imposed to meet this condition.

FIGURE 5A. PROBABILITY OF OCCURRENCE TEMPER
(LOWER MAXIMUM TEMPERATURE LIMIT) (TR



1

Y OF OCCURRENCE TEMPERATURES ≥ 103°F, WARMEST MONTH
IMUM TEMPERATURE LIMIT) (TRUCK, CARGO, 2-1/2-TON, 6 x 6, M35)

2

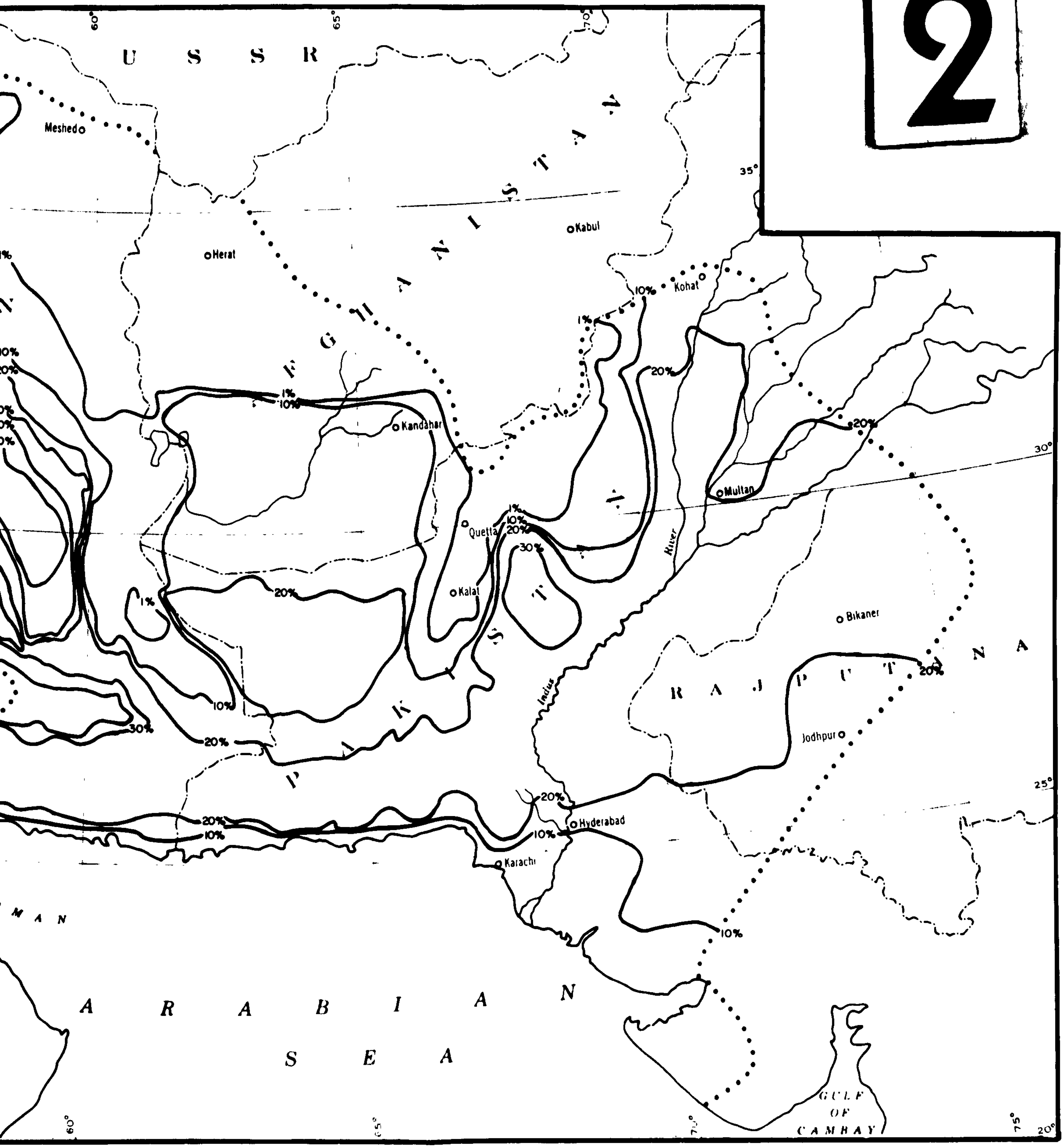
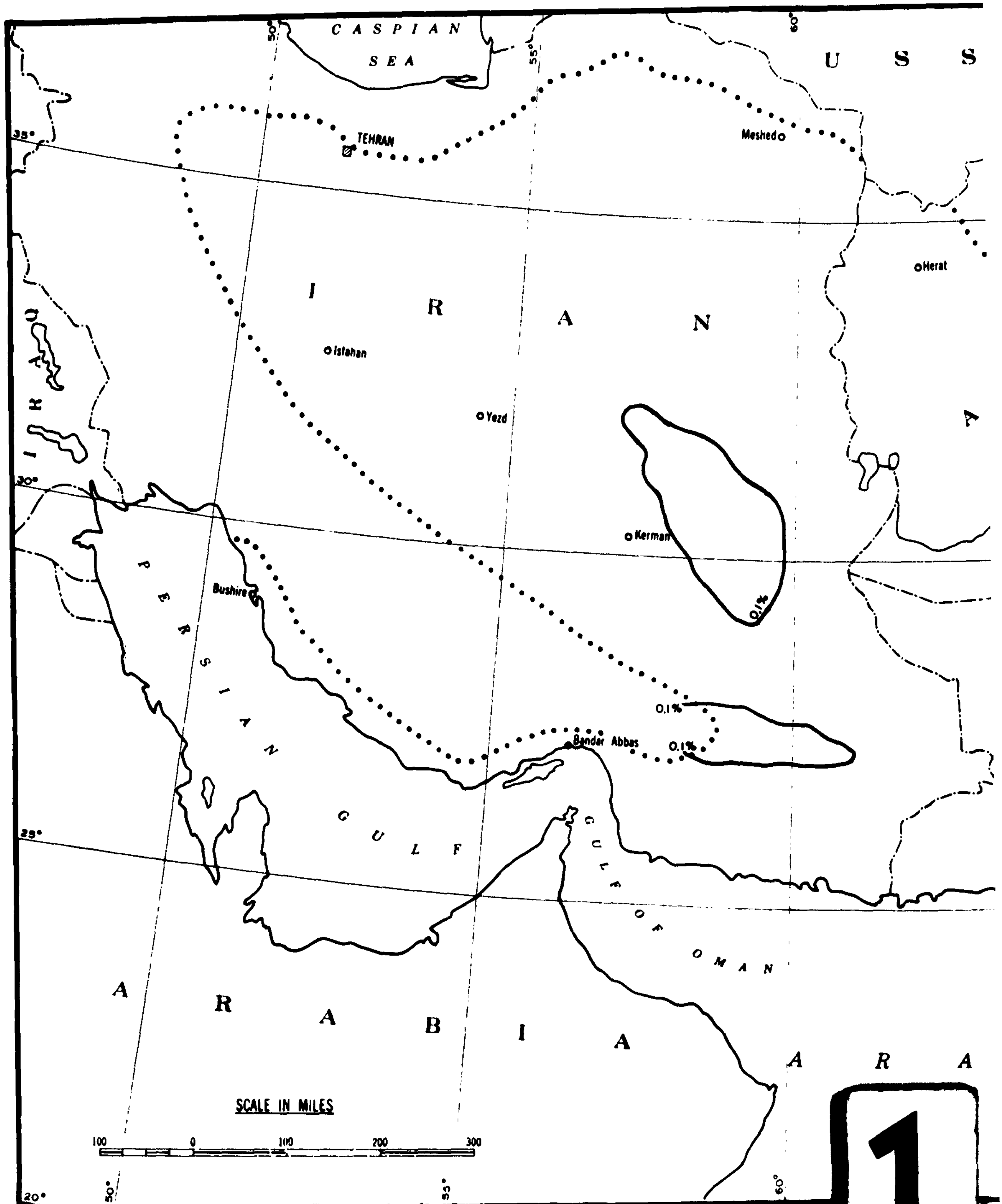
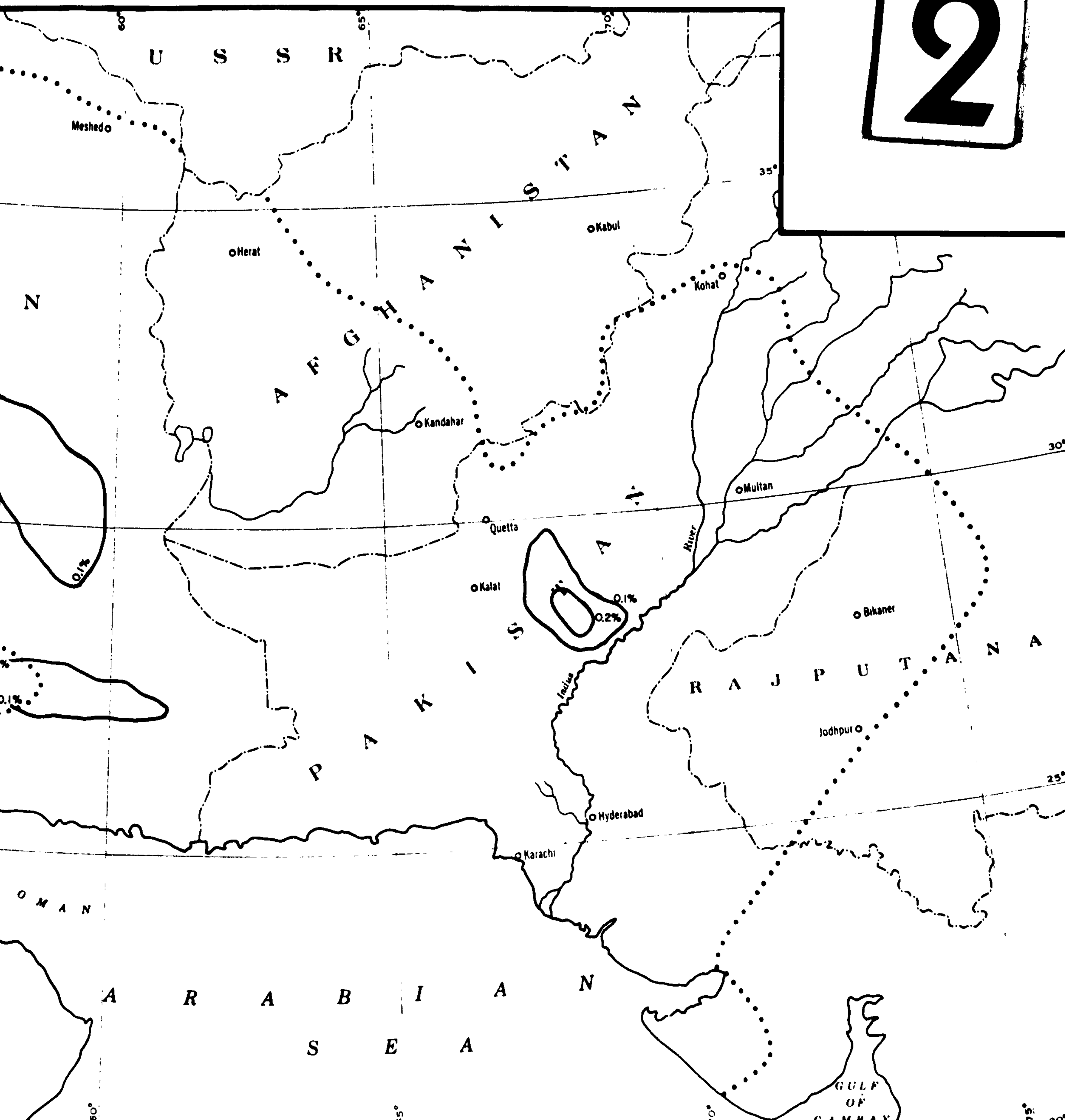


FIGURE 5B. PROBABILITY OF OCCURRENCE TEMP
(UPPER MAXIMUM TEMPERATURE LIMIT)



LITY OF OCCURRENCE TEMPERATURES ≥ 125°F, WARMEST MONTH
AXIMUM TEMPERATURE LIMIT) (TRUCK, CARGO, 2-1/2-TON, 6x6, M35)

2



Therefore, the following tabulation is indicative of those generalized landscape areas where sand dunes existed.

PP	SO	CS	CR	SC
5L//	4	3	5	5
6L//	3	3	5	5
6L	3	3	5	5
6	2	3	4	5
6	3	3	4	5
6	4	3	4	5

A final "No-Go" plotting occurred whenever the soil consistency was equal to a "3" as defined by the Corps of Engineers Data Coding System.

A "Doubtful" mobility condition existed whenever the characteristic slope was equal to or greater than 25%, but less than 50%. Therefore, the following tabulation is indicative of those generalized landscape conditions which existed that would qualify for this selection:

PP	SO	CS	CR
4	5	4	5
4	6	4	5

Finally, the "Selective" plot was used when there was some "No-Go" terrain conditions existing in complex situations with "Go" terrain conditions.

Figure 5C plots the mobility-terrain relationships.

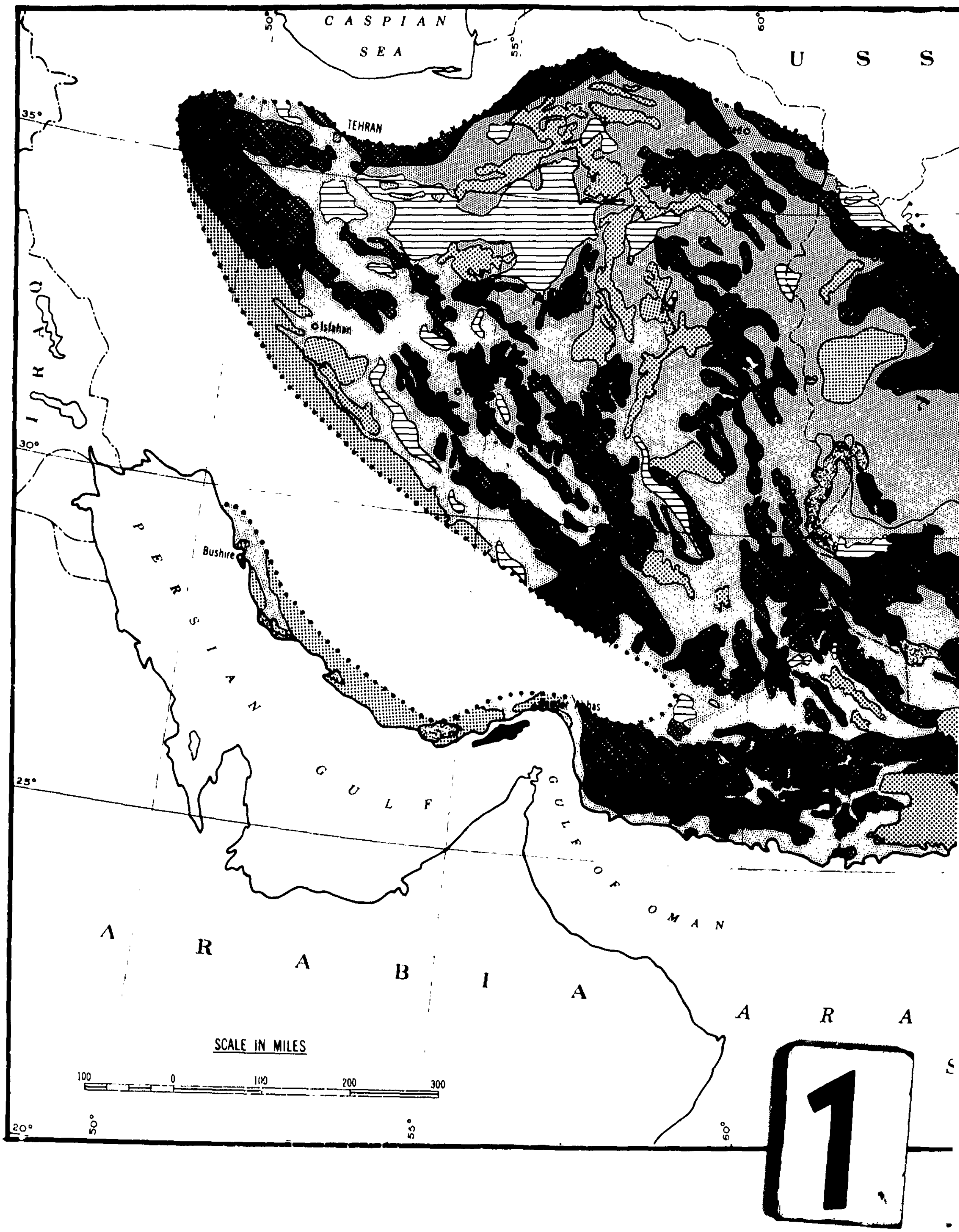
D. Carrier, Personnel, Full-Tracked, M113

The lower temperature limit of the M113 was determined to be 117°F and the upper temperature limit 125°F. This vehicle has a temperature dependent problem which involves the cooling of the transmission oil under conditions of the road load cooling test.

Figure 6A plots the probability of occurrence for temperatures equaling or exceeding 117°F during the warmest month in the South Asian desert. As with other analogs, this map presents an estimate of time in that month that temperatures will occur which would cause the M113 vehicle to exceed design specifications under certain operating conditions.

Figure 6B indicates the probability of occurrence for temperatures equaling or exceeding 125°F during the warmest month. This would be an

FIGURE 5C. MOBILITY-TERRAIN
(TRUCK, CARGO, 2-1/2-



5C. MOBILITY-TERRAIN RELATIONSHIP (TRUCK, CARGO, 2-1/2-TON, 6 x 6, M35)

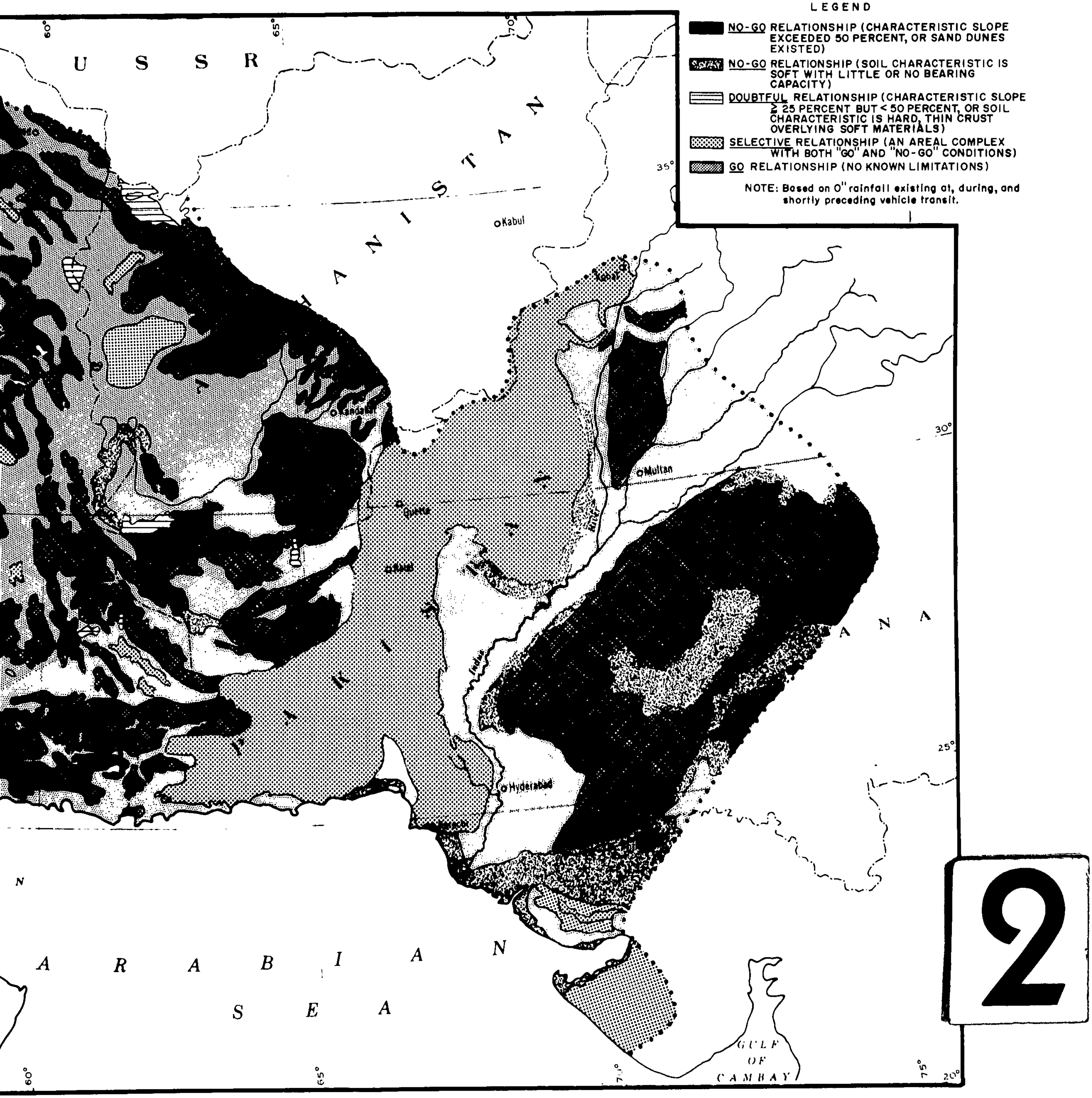
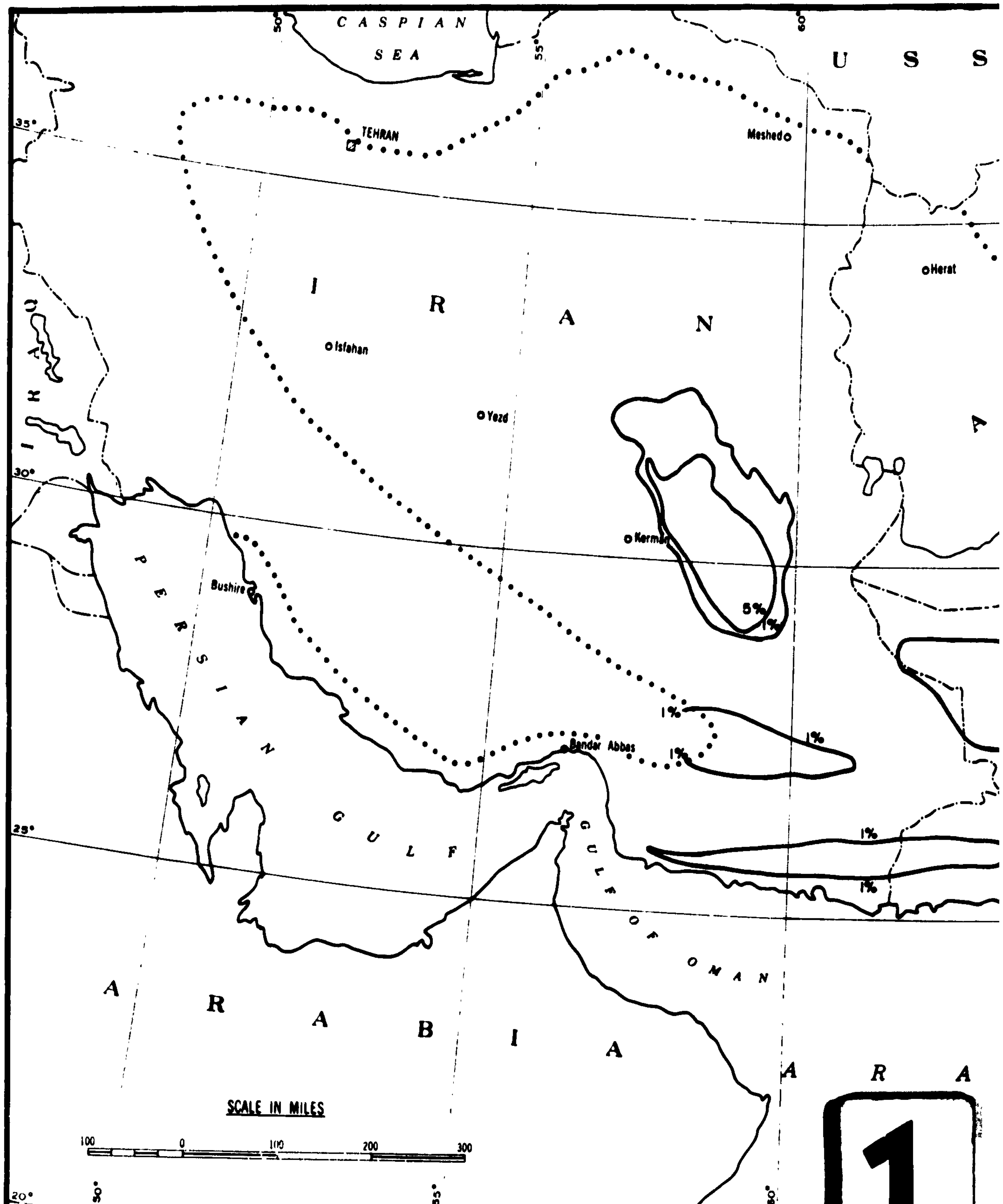


FIGURE 6A. PROBABILITY OF OCCURRENCE TEMP
(LOWER MAXIMUM TEMPERATURE LIMIT



1

LITY OF OCCURRENCE TEMPERATURES ≥ 117°F, WARMEST MONTH
AXIMUM TEMPERATURE LIMIT) (CARRIER, PERSONNEL, M113)

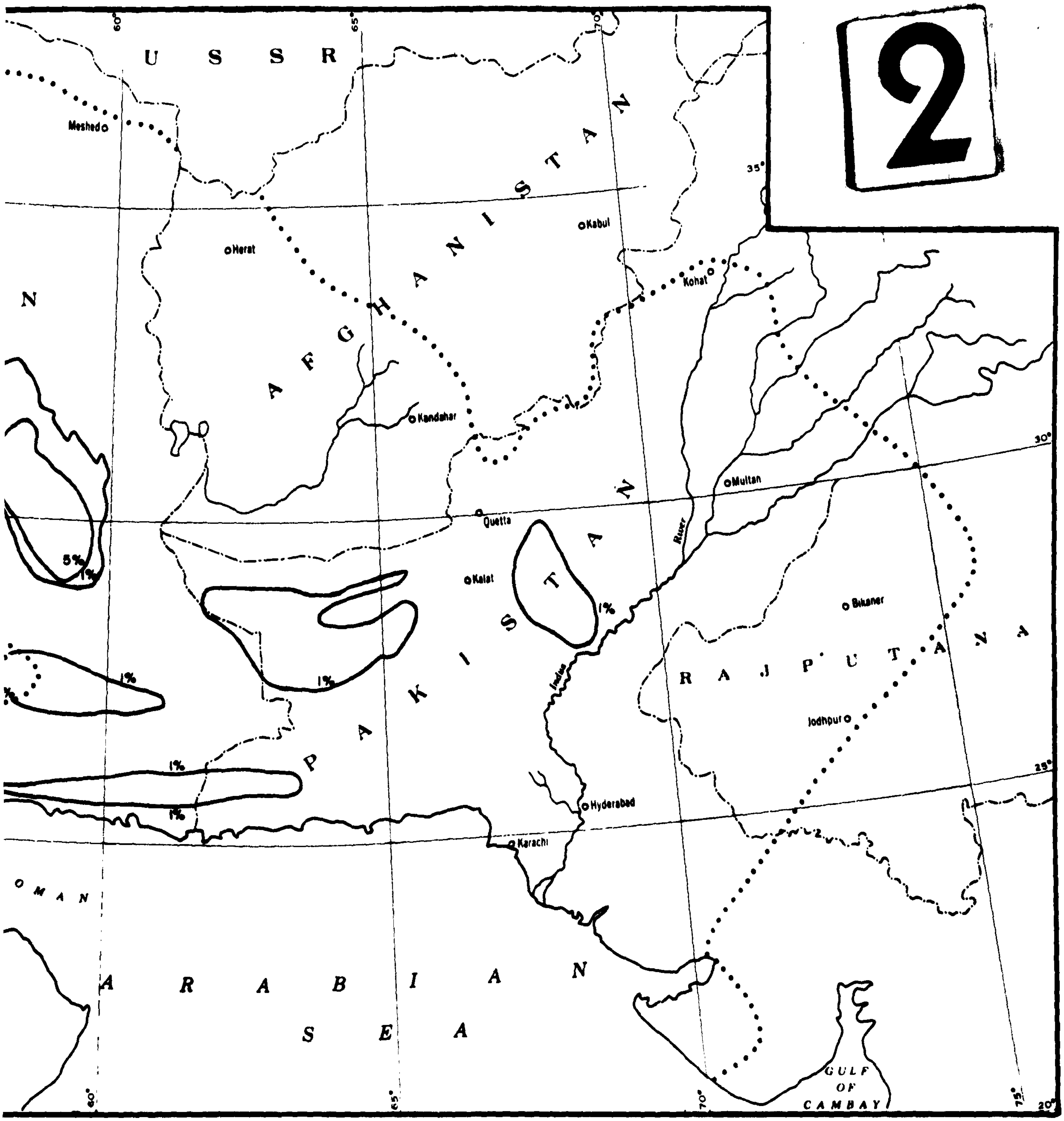
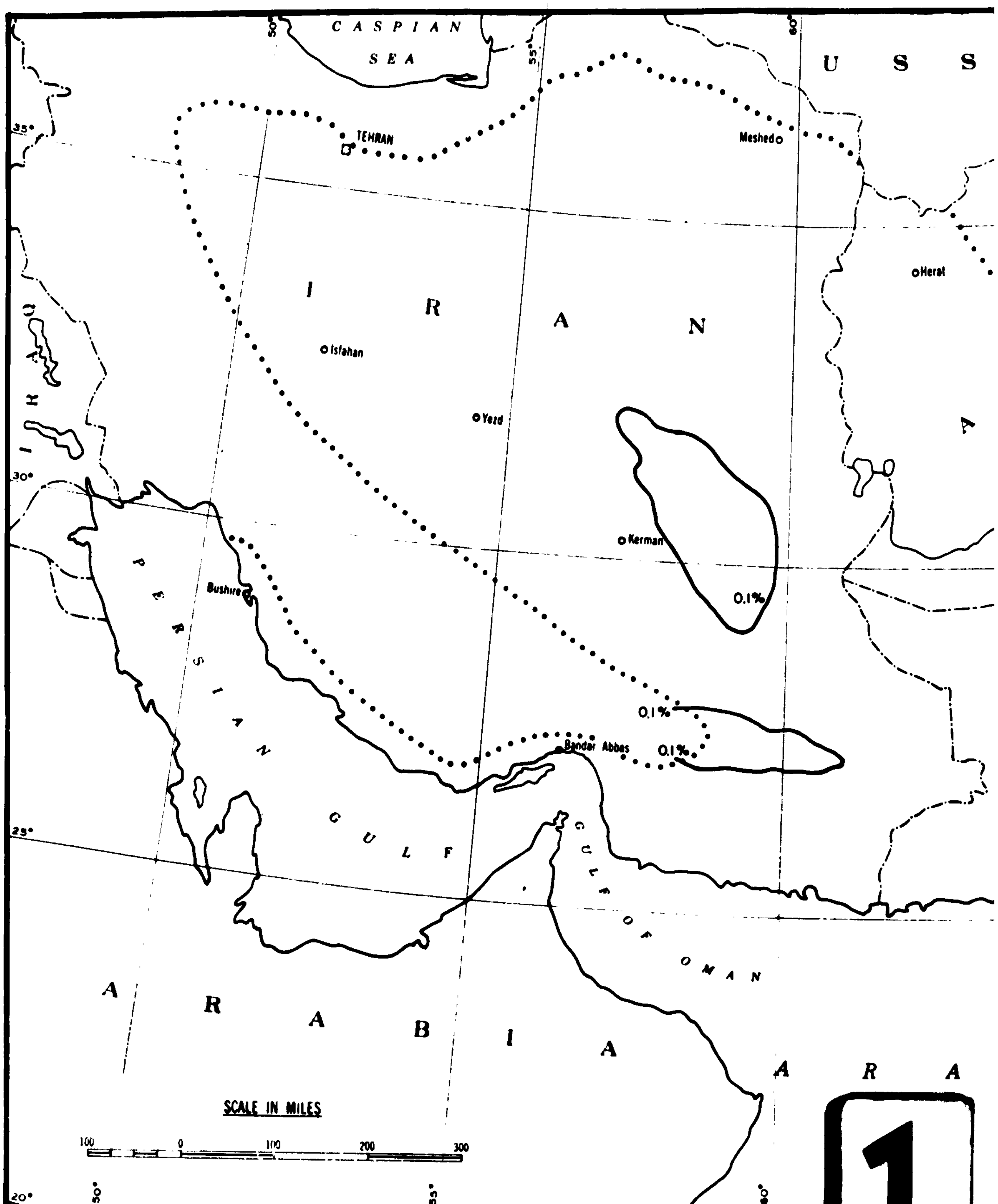
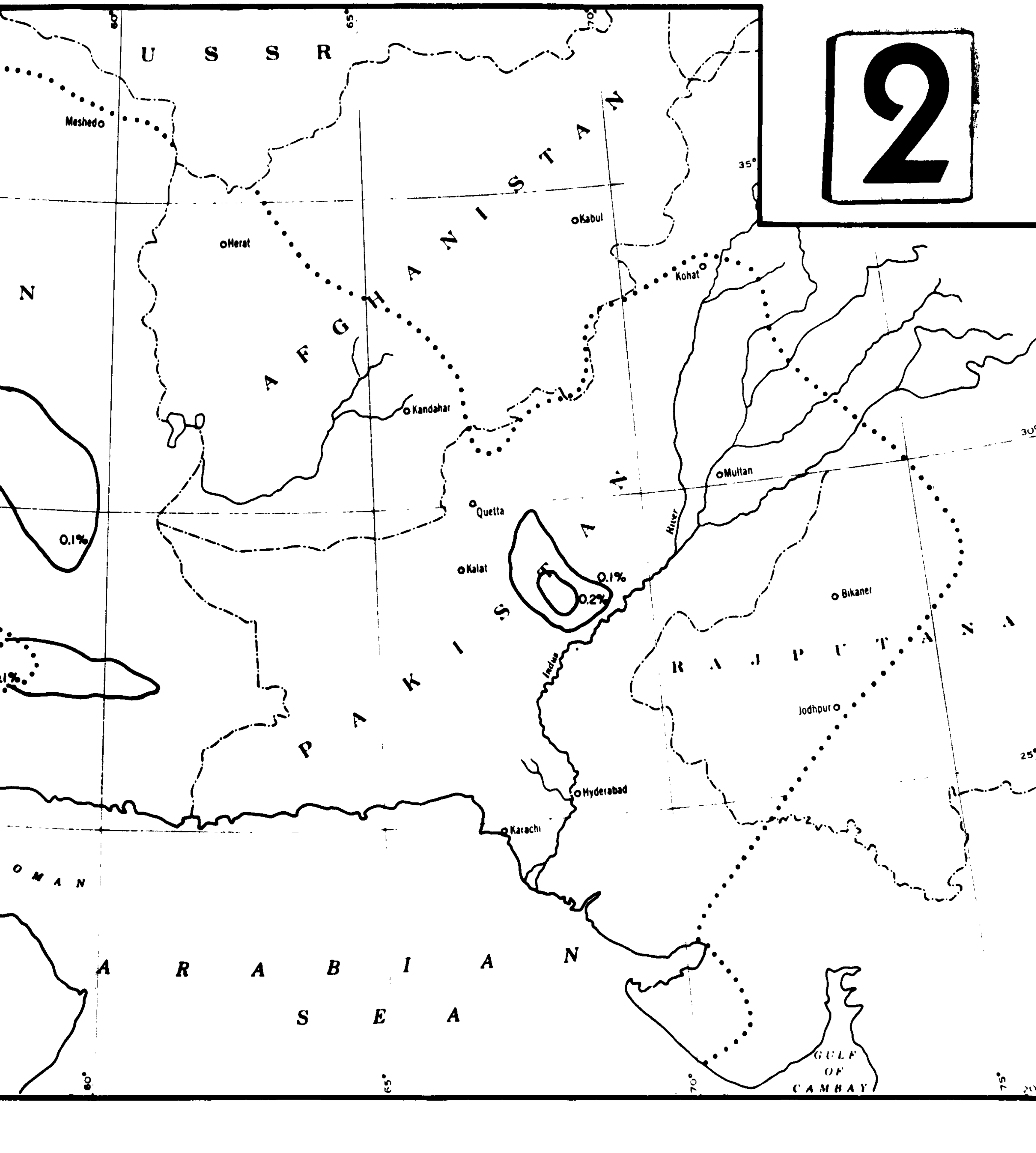


FIGURE 6B. PROBABILITY OF OCCURRENCE TEMPE
(UPPER MAXIMUM TEMPERATURE LIMIT) (C



ITY OF OCCURRENCE TEMPERATURES ≥ 125°F, WARMEST MONTH
XIMUM TEMPERATURE LIMIT) (CARRIER, PERSONNEL, M113)



2

estimate of the percentage of time for the month that any operation would be hazardous in the designated areas because of high ambient temperatures.

The test reports on this vehicle were generally satisfactory and few deficiencies or malfunctions could be isolated as major factors. The available performance test reports did not indicate the M113's maximum slope climbing ability. However, a field report was found which originated from a tropical exercise[6] in which is was stated the vehicle did not climb a 60 percent dry soil slope. For lack of other information, this value was taken as indicating the upper limit of the climbing ability of the M113. The Corps of Engineers plot of terrain gave 50 percent values as the nearest plot of terrain which could be used. Thus, the plot included herein uses the 50 percent slope value as indicating the upper slope limit.

The selection criteria for "No-Go" performance was as follows:

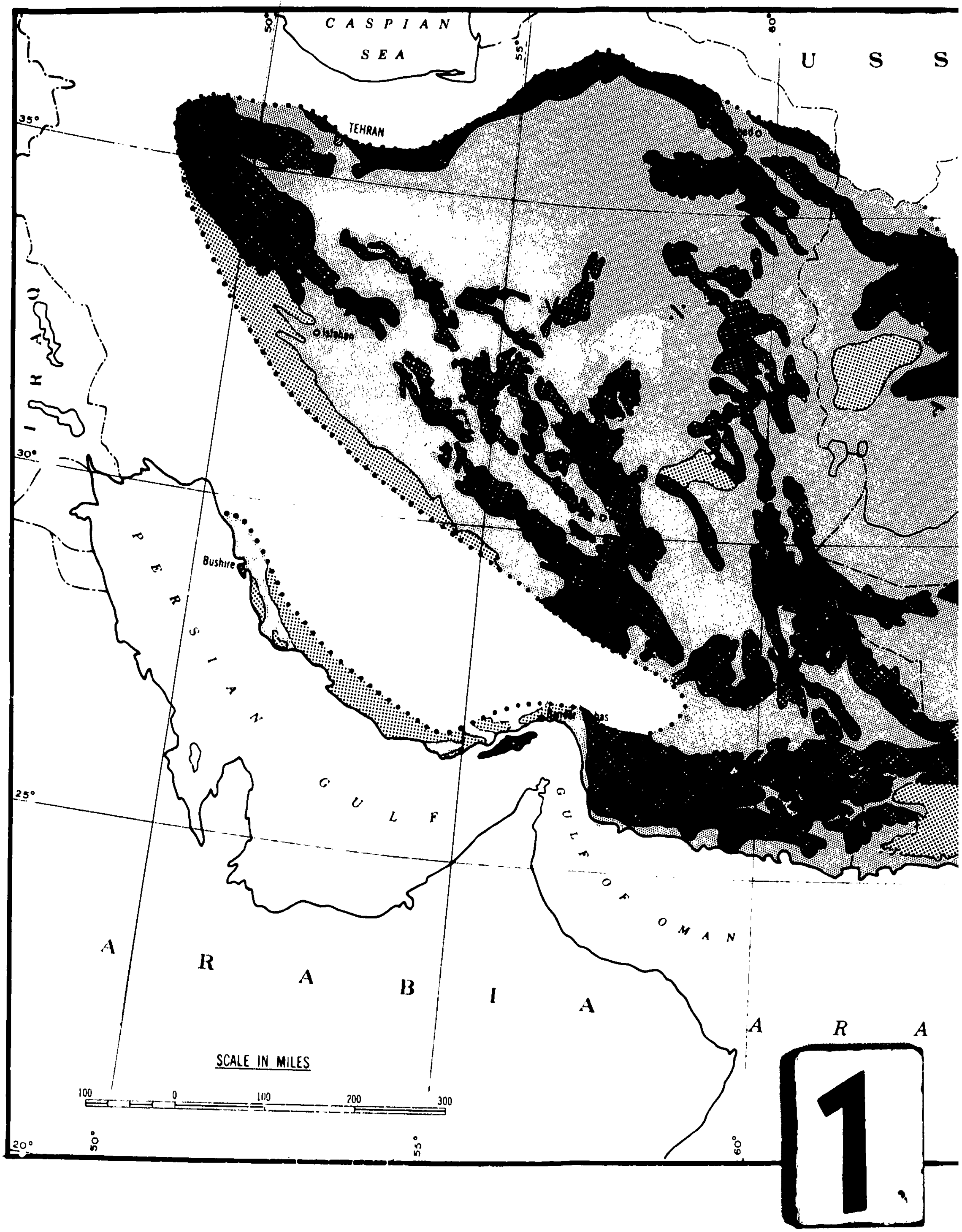
PP	SO	CS	CR
4	5	4	5
4	5	5	5
4	5	5	6
4	6	4	5
4	6	5	5
4	6	5	5
4	6	5	6
4	6	5	7
4L	5	5	5
4L//	6	5	6
4L//	6	5	7

There were no "Doubtful" plottings required for this vehicle. "Selective" plots were used whenever some complex terrain conditions occurred when the tabulated generalized land features occurred in combination with some features that were considered as "Go" for the vehicle.

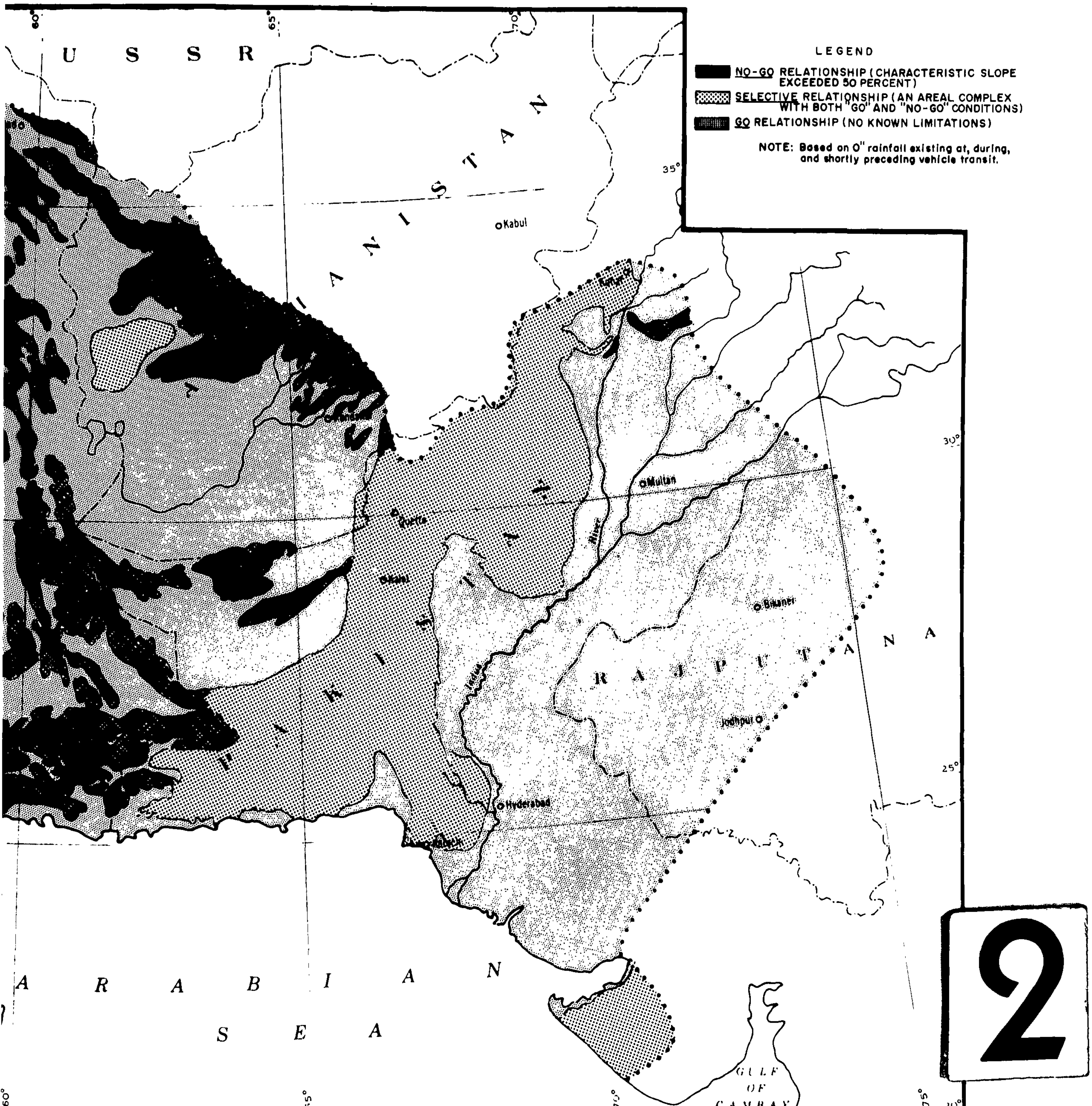
The mobility-terrain relationships are shown in Figure 6C.

(6)Mannheimer, R. J., The Wet Tropical Environment--Its Description and Effect on Materiel Performance, Southwest Research Institute, (Contract No. DA-23-072-ORD-1375. April 1962.

FIGURE 6C. MOBILITY-TERRAI
(CARRIER, PERSONN



. MOBILITY-TERRAIN RELATIONSHIP
(CARRIER, PERSONNEL, M113)



V. CONCLUSIONS AND RECOMMENDATIONS

This final chapter describes the conclusions of the study with respect to application of presently existing data in predicting equipment performance in any selected world environment. Further, it makes recommendations as to procedures that might be taken to improve the system.

A. Conclusions

General performance limits of a vehicle can be plotted for a given area. However, the degree of reliability of these plots is severely limited by the lack of definitive data relating vehicle performance to precise soil and terrain definitions, as developed by the Military Evaluation of Geographic Areas project.

Presently, there is no system or method of evaluation which adequately copes with the synergistic environmental effects. This quickly resolved this study to an evaluation of single environments, further reducing the precise scientific validity.

Negative-type plots of vehicle performance are the most feasible to use at present, due to current methods of reporting engineering performance data. This method of reporting is currently utilized to limit the scope of reporting and carries the implication that all other vehicle performance was satisfactory.

There is difficulty in isolating the implied results of what was satisfactory from those results which were not obtained at all. To do so requires close scrutiny and interpretation of the reports, and very often the entire test must be reconstructed in a subjective manner.

It was necessary to plot terrain factors as fixed variables, whereas climatic factors had to be plotted on the basis of probability of occurrence. Essentially, this implied that the terrain factor always occurs with a probability value of 100 percent for a given location and a given climatic occurence will be less than 100 percent for the same location.

Climatic plots should be plotted on the same mapping scale as the terrain features and, also, some consideration should be given to terrain features when constructing the climatic plot. For example, to mathematically average climatic conditions on a 20,000-ft mountain from its base

to the top at intervals of 1000 ft would yield a valid average, but, nevertheless, it would be unrealistic for field application These considerations are presently being made by the Quartermaster Corps in their latest mapping of climate, although these maps are still unpublished and evidently do not exist in the larger scale plots of the various areas.

Present methods of rating Envanal charts do not in all instances allow direct translation of performance to the plotting but do permit quick isolation of those problem areas which can be traced to and evaluated from the basic test report. In the methods presently used, performance is rated against a design specification. Thus, there is no guarantee that the design specification covers the maximum limit required by the environment, or that a limit of performance lies somewhere between the design specification limit and the limit imposed by the environment.

The analog type comparisons between the Yuma climate and terrain and the climate and terrain of the South Asian desert were not beneficial in predicting vehicle performance limits. This was because the analogies were based upon single, isolated environments, which seldom, within themselves, permitted logical deductions of performance constraints. For example, the degree of absolute maximum temperature analogy between the test site and some other location would be meaningless for predictive purposes unless a vehicle was actually tested at that absolute maximum temperature. Similar types of examples could be drawn for the other analogies, when considered separately.

The analogies when taken in total combination would so limit the area where predictions could be made as to again limit the usefulness of the procedure

The raw data used in preparing the climatic analogs and terrain analogs were valuable in relating vehicle performance with geographical location. The Corps of Engineers terrain maps, with some minor exceptions, provided the only basis for relating test site terrain with South Asian desert terrain. The Quartermaster Corps temperature data were sufficient to construct reasonably accurate distributions of occurrence for any specific point.

The different methods of terrain description used by the Corps of Engineers and vehicle test personnel were a severe handicap in estimating terrain-mobility capabilities for the South Asian desert.

B. Recommendations

In order to contrive a methodology and scientific approach to the practical development of the Envanal program, the following recommendations are submitted:

(1) It is recommended that the following types of maps developed by the U. S. Army Corps of Engineers be modified, standardized, and utilized in the development of the over-all Envanal program. (Subject reference is the Corps of Engineers report prepared by the Geology Branch, Soils Division, dated March 1959, entitled "Analogs of Yuma Terrain in the South Central Asian Desert," Copy 1.)

Plate 1--Characteristic Plan-Profile

Present form is considered adequate at this time without modification.

Plate 2--Slope Occurrence

Present form is considered adequate at this time without modification. This particular type of frequency map could also be prepared for frequencies other than 50 percent. It is recommended that this map be continued and consideration given as to what advantages could be obtained by additional maps of this form

Plate 3-- Characteristic Slope

This map is valuable, and modification if possible, is recommended to further reduce the four and five groups to more and smaller intervals, especially between the range of 25 to 75 percent slopes. Perhaps increments of ten percent would be more satisfactory than the use of the present 25 percent intervals

Plate 4 --Characteristic Relief

Present form is usable No modification is indicated

Plate 5--Generalized Landscape

This type of map is satisfactory in its present form and should be continued

Plate 6--Soil Type

This map is very useful, although some modification appears in order. This map represents a particle size distribution classification, except for the "saline" category which represents a type of mineral or pH classification. The use of saline on this map appears inconsistent with the over-all map. Additional subdivision of the first three groups into a particle size classification also appears in order.

Plate 7--Soil Consistency

This map is useful in its present form. No modification is indicated.

Plate 8--Surface Rock

This map may prove of value and should be continued; however, the classification for the type of use considered in this report is limited and would be more valuable if the size and frequency of the surface rock were shown. The recommended modification of Plate 6 is also applicable to Plate 8

Plate 9--Vegetation

This map is considered usable in its present form.

Plate 16--Hypsometry

This map is considered valuable and usable in its present form.

(2) It is recommended that the Quartermaster Corps' climatic data be furnished in a probability of occurrence form for at least temperature and rainfall. Later such information could be made available pertaining to other climatic factors. It is recommended that all data be compiled on a monthly basis using the calendar month as standard for any and all types of Envanal application. Quarterly or seasonal summation could be used to reduce the work load; however, since spring, summer, winter, and fall seasons vary with positions on the earth, it is recommended that the monthly basis be used

All climatic plots should be in relation to terrain conditions and, when possible, corrected accordingly.

(3) It is recommended that terrain and climatic factors be standardized. Engineering test personnel should be required to record the appropriate data which would encompass all of the factors encountered during the test, and to define the performance which occurred according to specifically defined performance characteristics

(4) It is recommended that an Envanal chart or form be designed that will permit the entry of measured performance without regard to design specifications. This chart would list the selection of climatic and terrain characteristics according to the standardized form.

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4. Analogs of Yuma Terrain in South Central Asian Desert (18 plates), March 1959 Geology Branch, Soils Division, U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss

5. U.S Army Ordnance Corps Envanal Charts, Self-Propelled Automotive Equipment, Desert, 1961. Southwest Research Institute, San Antonio, Texas (Contract DA-23-072-509-ORD-8).

6. U.S. Army Ordnance Corps Envanal Charts, Self-Propelled Automotive Equipment, Arctic, 1961. Southwest Research Institute, San Antonio, Texas (Contract DA-23-072-509-ORD-8).

7. U.S Army Ordnance Corps Envanal Charts, Arms and Ammunition Equipment, Arctic, 1961. Southwest Research Institute, San Antonio, Texas (Contract DA-23-072-509-ORD-8).

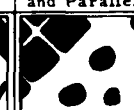
APPENDIX A

CORPS OF ENGINEERS DESERT TERRAIN ANALOG CODING SYSTEM

CHARACTERISTIC PLAN-PROFILE (PP)

The characteristic plan-profile is the most commonly found plan-profile within a region. It may be either restrictive or gross. The restrictive plan-profile is based on random sampling with circles 1 mile in diameter. Local relief of less than 10 ft is not considered. The gross plan-profile is based on random sampling with circles 35 miles in diameter. Relief of less than 100 ft is not considered. The prominences in such a plan-profile are termed component highs, the intervening lowlands component lows.

LEGEND

	Highs* Occupy:	Highs are →	Schematic Plan / Schematic Profile	Non-linear and Random	Linear and Random	Non-linear and Parallel	Linear and Parallel
							
1	>60% of area	Flat-topped		1	** 1L	*** 1//	1L //
2	40-60% of area	Flat-topped		2	2L	2 //	2L //
3	<40% of area	Flat-topped		3	3L	3 //	3L //
4	>60% of area	Crested or Peaked		4	4L	4 //	4L //
5	40-60% of area	Crested or Peaked		5	5L	5 //	5L //
6	<40% of area	Crested or Peaked		6	6L	6 //	6L //
	No pronounced highs or lows			7			

PLAN-PROFILE COMPLEXES:

Areal Complexes: Confined to areas where two major, areally restricted plan-profiles, both of the restrictive type are mapped.

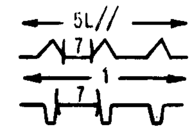
1/4 Plan-profile of the areally predominant lows.
Plan-profile of the areally subordinate highs.

1\4 Plan-profile of the areally predominant highs.
Plan-profile of the areally subordinate lows.

Gross-Component Complexes: Confined to areas where a gross and a restrictive plan-profile of either a component high or a component low are mapped.

$\frac{5L//}{7}$ Gross plan-profile
Restrictive plan-profile of component lows

1|7 Gross plan-profile
Restrictive plan-profile of component highs



*Highs are considered to be (1) peaked or crested prominences which exhibit characteristic slopes greater than 6 degrees or (2) fairly flat-topped prominences or high-level areas bounded by slopes in excess of 14 degrees.

**L indicates linearity of highs. A high is considered to be linear when its length is greater than 5 times its width.

***// indicates roughly parallel arrangement of highs or aligned highs.

OCCURRENCE OF SLOPES GREATER THAN 50 PERCENT (SO)

Occurrence may be either restrictive or gross. A restricted occurrence class indicates a modal range of slopes greater than 50 percent found along traverses containing the maximum number of such slopes. Relief of less than 10 ft is not considered. A gross occurrence indicates the modal distance between component highs or component lows. Relief of less than 100 ft is not considered.

1. The number of slopes steeper than 50 percent is less than 1 per 10 miles or in areas, less than 10 miles in maximum dimension, where such slopes are lacking.

2. The number of slopes steeper than 50 percent ranges from 1 to 5 per 10 miles.

3. The number of slopes steeper than 50 percent ranges from 5 to 20 per 10 miles.

4. The number of slopes steeper than 50 percent ranges from 20 to 100 per 10 miles.

5. The number of slopes steeper than 50 percent ranges from 100 to 200 per 10 miles.

6. The number of slopes steeper than 50 percent exceeds 200 per 10 miles.

OCCURRENCE COMPLEXES: (Mapped only where plan-profile complexes are mapped.)

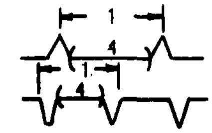
Areal Complexes: Confined to areas where two major, areally restricted occurrence units, both of the restrictive type, are mapped.

3/5 — Slope occurrence of areally predominant lows.
Slope occurrence of areally subordinate highs.

1\3 — Slope occurrence of areally predominant highs.
Slope occurrence of areally subordinate lows.

Gross-component Complexes: Mapped only where gross-component plan-profile complexes are mapped.

$\frac{1}{4}$ Gross occurrence of component highs.
Restrictive occurrence within component lows.



1|4 Gross occurrence of component lows.
Restrictive occurrence within component highs.

CHARACTERISTIC SLOPE (CS)

Slope is defined as a surface identified or designated in terms of its deviation from the horizontal. Characteristic slope is defined as a narrow range of slopes which predominates or is most common within a region (possessing a distinctive spacing, arrangement, or pattern of contour lines) mapped with a 10-ft contour interval.

Flat: Characteristic slope between 0 and 2 degrees (approx. 0 - 3.5%)

1a Between 0 and 1/2 degree (approx. 0 - 1%).

1b Between 1/2 and 2 degrees (approx. 1 - 3.5%).

2 Gentle: Characteristic slope between 2 and 6 degrees (approx. 3.5 - 10%).

3 Moderate: Characteristic slope between 6 and 14 degrees (approx . 10 - 25%).

4 Declivitous: Characteristic slope between 14 and 26.5 degrees (approx. 25 - 50%).

5 Steep: Characteristic slope between 26.5 and 45 degrees (approx. 50 - 100%).

6 Precipitous: Characteristic slope greater than 45 degrees (greater than 100%).

SLOPE COMPLEXES: (Mapped only where plan-profile complexes are mapped)

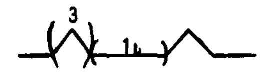
Areal Complexes: Confined to areas where two major, areally restricted slope types are mapped.

2/4 Characteristic slope of areally predominant lows.
Characteristic slope of areally subordinate highs.

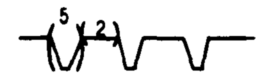
1b\3 Characteristic slope of areally predominant highs.
Characteristic slope of areally subordinate lows.

Gross-component Complexes: Mapped only where gross-component plan-profile complexes are mapped. The symbols in the complex are arranged vertically or horizontally depending on the plan-profile.

3 / 1b — Characteristic slope within component highs.* / Characteristic slope within component lows.



5 | 2 — Characteristic slope within component lows.* / Characteristic slope within component highs.



Important Scarps: An important scarp is defined as a more or less continuous precipitous slope exhibiting more than 100 feet of relief. Only the better known scarps which extend for considerable distances have been mapped. Scarp height is indicated where known.

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*In cases where the gross plan-profile is flat-topped or flat-bottomed, the characteristic slope is considered to be the modal slope of the bounding inclines.

CHARACTERISTIC RELIEF (CR)

Characteristic relief may be either restrictive or gross. Restrictive relief is based on modal classes of stream depth, elevation differential per unit area, or prominence height. This is further defined under type I and type II relief, below. Gross relief indicates the modal height of component highs or the modal depth of component lows.

I. RELIEF IN AREAS WHERE THE CHARACTERISTIC SLOPE IS LESS THAN 6 DEGREES (APPROX. 10 PERCENT)

Relief is defined as the modal vertical distance from interfluve crest to the immediately adjacent flow line.

1 Characteristic relief between 0 and 10 feet.

2 Characteristic relief between 10 and 50 feet.

3 Characteristic relief between 50 and 100 feet.

II. RELIEF IN AREAS WHERE THE CHARACTERISTIC SLOPE IS GREATER THAN 6 DEGREES (APPROX. 10 PER CENT)

Relief is defined as the modal maximum difference in elevation per square mile, or in areas where drainage lines are poorly developed or lacking*, from summit to adjacent low.

*Usually restricted to sand dune areas--maximum height of dunes indicated where known.

4 Characteristic relief between 0 and 50 feet.

5 Characteristic relief between 50 and 400 feet.

6 Characteristic relief between 400 and 1,000 feet.

7 Characteristic relief greater than 1,000 feet.

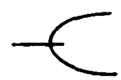
RELIEF COMPLEXES: (Mapped only where plan-profile complexes are mapped.)

Areal Complexes: Confined to areas where two major, areally restricted relief units, both of the restrictive type, are mapped.

2/5  Relief of areally predominant lows.
Relief of areally subordinate highs.

5\2  Relief of areally predominant highs.
Relief of areally subordinate lows.

Gross-component Complexes: Mapped only where gross-component plan-profile complexes are mapped.

$\frac{5}{1}$  Gross relief of component highs
Restrictive relief within component lows

5|2  Gross relief of component lows
Restrictive relief within component highs

Important Scarps: A scarp is defined as a more or less continuous precipitous slope exhibiting more than 100 feet of relief. Only the better known scarps which extend for considerable distances have been mapped. Scarp height is indicated where known.

SOIL TYPE (ST)

I. SOIL-ROCK ASSOCIATIONS

1 Areas characterized by a mosaic of bare rock and stony soils* with a few scattered patches of coarse- and fine-grained soils. Bare rock and stony soils cover more than 90 percent of the area mapped.

2 Areas characterized by a mosaic of bare rock and stony soils with numerous patches of coarse- and fine-grained soils. Bare rock and stony soils cover from 50 to 90 percent of the area mapped.

3 Areas characterized by a mosaic of coarse- and fine-grained soils with numerous rock and stony soil outcrops. Bare rock and stony soils cover from 20 to 50 percent of the area mapped.

Areas where patches of soil consist of unconsolidated deposits of volcanic ash or ejecta.

*Stony soils: More than 75 percent of a typical sample consists of material coarser than gravel. Coarse-grained soils: More than 50 percent of a typical sample consists of sand and/or gravel. Fine-grained soils: More than 50 percent of a typical sample consists of silt and/or clay.

II. SOIL ASSOCIATIONS

Areally predominant (70 percent or more) soil type mapped. Area mapped never includes more than 20 percent bare rock and stony soils.

4	COARSE	Gravel: More than 90 percent of a typical sample consists of gravel.
5	GRAINED	Sand: More than 90 percent of a typical sample consists of sand.
6	SOILS	Sand and Gravel mixed with minor amounts of finer material: More than 50 percent of a typical sample consists of sand and/or gravel.

7		Silt and clay with minor amounts of coarser material: More than 50 percent of a typical sample consists of silt and/or clay.
8	FINE	Silt: More than 75 percent of a typical sample consists of silt.
9	GRAINED	Clay: More than 75 percent of a typical sample consists of clay.
10	SOILS	Saline: A typical soil sample has a salt content of more than 25 percent--usually associated with silt and clay.
5/4		SOIL COMPLEXES: Soil complexes are mapped where no areally predominant (70 percent or more) soil type occurs. In such instances, the two most commonly occurring soil types are mapped; the predominant is shown as the numerator, the subordinate as the denominator in the fractional pattern.

SOIL CONSISTENCY (SC)

Soil consistencies are mapped only where soil associations occur. Areally predominant (70 percent or more) soil consistency mapped.

I. HOMOGENEOUS CONSISTENCIES: Soils of essentially unchanged consistencies to depths greater than 12 inches.

A. Noncohesive: Materials in which the constituent particles do not adhere to each other.

1 Loose: The ratio of voids to constituent grains is close to a naturally occurring maximum, i.e., the grains are loosely packed.

2 Dense: The ratio of voids to constituent particles is close to a naturally occurring minimum, i.e., the grains are closely packed.

B. Cohesive: Materials in which the constituent particles adhere to each other, either because of mutual attraction of the particles themselves, or because of the presence of a cementing material.

3 Soft (usually perennially wet): Little or no bearing capacity.

4 Firm: Moderate bearing capacity.

5 Hard: High bearing capacity.

II. LAYERED CONSISTENCIES: Soils possessing two or more relatively discrete layers within 12 inches of the surface.

A. Crusted surfaces: Surface crust may be either cohesive or noncohesive.

6 Hard thin crust (commonly of cemented materials) overlying soft materials (commonly muck, ooze, or saturated silts).

7 Hard crust (commonly of cemented materials) overlying noncohesive material (commonly sand or silt).

8 Thin zone of firm materials over noncohesive materials. (Most common development in areas of fixed dunes, with more or less continuous vegetation cover.)

9 Surface of closely fitted noncohesive pebbles or gravel overlying noncohesive materials (commonly sand or silt).

(Such "desert pavements" also occur over bedrock or materials of firm consistencies, but this is less common.)

B. Noncohesive surface layer less than 12 inches thick.

10 Dense layer within 12 inches of the surface.

11 Hard layer within 12 inches of the surface (usually, but not always, caliche).

3/4 CONSISTENCY COMPLEXES: Consistency complexes are mapped where no areally predominant (70 percent or more) consistency occurs. In such instances, the two most commonly occuring consistencies are mapped; the predominant is shown as the numerator, the subordinate as the denominator in the fractional pattern.

SURFACE ROCK (SR)

Mapped in regions where rock is exposed and at shallow depths (i.e., 0-10 feet)* throughout the remainder of the area. In effect this procedure restricts the mapping of surface rock to areas mapped as 1, 2, or 3 under Soil Type.

Areally predominant (70 percent or more) rock type mapped.

1 IGNEOUS (UNDIFFERENTIATED): Rocks formed by solidification or crystallization of a hot fluid mass.

2 Intrusive: Ingneous rocks, typically crystalline, which have formed by cooling below the surface of the earth. (Granite, syenite, diorite, etc.)

3 Extrusive (undifferentiated): Igneous rocks which have formed by cooling at the surface of the earth.

3a True extrusive rocks formed by solidification of molten material that poured out on the surface of the earth (e.g , basalt, dacite, etc.).

3b Rocks formed by secondary cementation of loose deposits of volcanic ejecta (e.g., tuff, agglomerate, etc.).

4 METAMORPHIC (UNDIFFERENTIATED): Rocks formed from original ingneous or sedimentary rocks throughalterations produced by pressure, heat, or the infiltration of other materials at depths below the surface zones of weathering and cementation. The alterations are sufficiently complete throughout the body of the rock to produce a well-defined new type. (Gneiss, schist, slate, etc)

5 SEDIMENTARY (UNDIFFERENTIATED) Rocks formed from material laid down in a more or less finely divided state, as sediment, through the agency of water, wind, or glaciers.

6 Sandstone. A sedimentary rock predominantly composed of sand grains cemented together.

7 Limestone: A sedimentary rock consisting essentially of calcium carbonate.

8 Shale: A sedimentary rock in which the constituent particles are predominately of clay size.

9 Evaporites: A sedimentary rock whose origin is largely due to evaporation and subsequent precipitation of salt from water. (Gypsum, anhydrite, and rock salt are the only evaporites of quantitative importance.)

3a/3b ROCK COMPLEXES: Rock complexes are mapped where no areally predominant (70 percent or more) rock type occurs. In such instances, the two most commonly occurring rock types are mapped; the predominant is shown as the numerator, the subordinate as the denominator in the fractional pattern.

*It should be realized that the scale of mapping precludes delineation, especially in mountanious regions, of many alluvial basins where the thickness of soil cover is much greater than 10 feet.

Note: Tabulation of generalized rock properties on reverse side.

VEGETATION (V)

Areally predominant (70 percent or more) vegetation type mapped.

Unit		Description
1	Barren	Devoid or nearly devoid of vegetation.
2	Sparse shrub & grass	Widely spaced thorny shrubs, bushes, low scrubby trees, herbs, or clumps and open stands of coarse grass. (Also includes cacti in the U.S.)
3	Scattered shrub & grass	Moderate spacing of forms mentioned under unit 2.
4	Scattered shrub and/or scrubby trees	Thin stands of shrubs and scrubby trees, undergrowth (if present) consists of low shrubs, bushes, and grasses.
4a	a. With scattered 3rd-story trees	------------------------------------
5	Dense shrub and/or scrubby trees	Dense stands of shrubs and scrubby trees, undergrowth (if present) consists of low shrubs, bushes, and grasses.
5a	a. With scattered 3rd-story trees	------------------------------------
5b	b. With grain-herb cultivation	Orchard areas with grain-herb cultivation forming the 1st story.
6	Palms with or without grain-herb cultivation	Dense palm groves, 1st-story grain-herb cultivation may or may not be present.
7	Steppe	Low grass cover, may or may not include scattered low scrubby trees and shrubs. Height of grass ranges from a few inches to 2 feet.

8	Steppe-savanna	High continuous grass cover, includes scattered scrubby trees and shrubs. Height of grass averages 3-5 feet.
9	Grain-herb cultivation	Cultivated plots of grains, vegetables, etc.
10	Marsh	Dense growth of grasses, sedges, etc.
2/4	VEGETATION COMPLEXES	Vegetation complexes are mapped where no areally predominant (70 percent or more) vegetation type occurs. In such instances, the two most commonly occurring types are mapped; the predominant is shown as the numerator, the subordinate as the denominator in the fractional pattern.

APPENDIX B

SUMMARY OF VEHICLE PERFORMANCE CHARACTERISTICS

M48 TANK, COMBAT, FULL-TRACKED, 90MM GUN

Performance and Physical Characteristics Pertinent to Desert Terrain Operation

A. Mobility

Satisfactory in all terrains tested. Mobility tested in hard prepared surfaces, rocky ground, loose gravel, alluvial fans, mountainous, and (T48) in dune sand. On over 40% sand slopes, track slippage occurred (TT2-760/1).

B. Cooling

Cooling characteristics are satisfactory at 107°F, marginal at 115°F, and critical at 125°F (ambient temperature). The M48 will not cool satisfactorily above an ambient of 100°F in the low range, full throttle condition (TB5-1401/195). Cylinder heads on the main engine will overheat, and the main engine oil temperature will be borderline at an ambient of 125°F.

C. Vapor Lock

The main engine operated without failure due to vapor lock, and, although the fuel pressure to and at the carburetor reached as low as 0.5 psi, no malfunction at the engine was observed (TB5-1401/195) The modified fuel system, with the relocated fuel filter for the main engine, operated satisfactorily during vapor lock tests and would operate satisfactorily at 125°F using MIL-G-3056 specification fuel (TB5-1401/195)

D. Endurance

	TB5-1401/112	TB5-1401/195	TB5-1401/216
Paved surfaces	Satisfactory	Gen Satis	--
Alluvial fans	Satisfactory	Gen Satis	Gen Satis
Desert pavement	Satisfactory	Gen. Satis.	Gen. Satis
Hill or Mountainous	--	Gen. Satis.	--
Dust (airborne)	--	--	Gen Satis
Temperature (test ambient)	Satisfactory	--	Gen Satis Gen Satis

E. <u>Pertinent Physical Characteristics: (ST9-159)</u>

Ground pressure (combat loaded): 11.5 psi

F. <u>Pertinent Performance Factors: (ST9-159)</u>

Fordability	48"
Gradeability	60%
Vertical Climb	36"
Trench Crossing	102"

M274 (XM274) CARRIER, LIGHT WEAPONS, INFANTRY, 1/2-TON, 4 X 4

Performance and Physical Characteristics Pertinent to Desert Terrain Operation

A. <u>Mobility</u>

The M274 has satisfactory mobility characteristics; however, caution must be taken during dune sand (or similar terrain)operation to prevent head slippage if the tires have been deflated for better traction. Operation on longitudinal paved slopes up to 60% and side slopes up to 40% was normal (IT-5033/2 APG). The M274 could not traverse any freshly disced slope at any tire pressure with appreciable speed (TB-1401-458) Satisfactorily operated on prepared sand slopes up to 20% gradient (TB5-1401/458).

B. <u>Cooling</u>

The M274 will cool satisfactorily under most road-load and cross-country conditions to 115°F, however, during operation in soft sand or steep hills, engine oil temperatures will exceed specification at 100°F. Full-throttle cooling has been unsatisfactory in all test ambients (95-104°) (TB5-1401/458).

C <u>Vapor Lock</u>

Vapor handling facilities are satisfactory to 125°F (fuel equivalent to 8 psi rvp at 125°)

D. <u>Endurance</u>

Generally satisfactory under all kinds of desert environment. Various mechanical deficiencies not attributable to environment.

E. <u>Pertinent Physical Characteristics: (ST9-159)</u>

Ground clearance 11.75"

F <u>Pertinent Performance Characteristics (TB5-1401/458)</u>

Fordability	18"
Vertical Climb	24"
Gradeability	Paved 60%, prepared sand slopes 20%

M35 TRUCK, CARGO, 2-1/2-TON, 6 X 6

Performance and Physical Chracteristics Pertinent to Desert Terrain Operation

A. Mobility

The M35 with dual tires will operate satisfactorily over the common desert terrain but is limited to carefully reconnoitered trails or prepared roadways in the sand dune areas (TB5-1401/27). Slope gradeability tests run on disc harrowed sand slopes indicated the M35 would perform satisfactorily within reasonable limits, with the rated cross-country payload. The practicable tire pressures with respect to grade and load factors are (TB5-1401/Y29):

% Slope	Payload - Empty	Payload, 5000 lb	5000- and 7900-lb Towed Load
10	12 lb	10 lb	5 lb
15	6 lb	10 lb	5 lb
20	2 lb	5 lb	"No-Go"

B. Cooling

Cooling characteristics, while unsatisfactory in ambients above 100°F with the standard vehicle, can be improved to marginal performance in 125°F by using six-blade fans and oil coolers (TB5-1401/276).

C. Vapor Lock

Vapor handling characteristics are satisfactory if a submerged electric fuel pump is used (TB5-1401/276). With a standard fuel pump, incipient vapor lock encountered under severe operating conditions using fuel adjusted to 8 psi rvp at 125° (TB5-1401/78).

D. Endurance

Functioning and endurance characteristics are satisfactory under all environments.

E. <u>Pertinent Physical Characteristics: (ST9-159)</u>

Ground clearance 1' 2"

F. <u>Pertinent Performance Characteristics: (ST9-159)</u>

Gradeability	60% (hard surfaced road)
Fordability	30" w/o equipment

M113 CARRIER, PERSONNEL, FULL-TRACKED

Performance and Physical Characteristics Pertinent to Desert Terrain Operation

A. Mobility

Excellent over all tested desert terrain - no validated test for dune sand, but dune sand test of T113 indicated a totally unsatisfactory rating (TB5-1401/400). Also, TB1401/400 (T117) indicates vehicle became immobilized in a swampy area. Mobility on prepared sand slopes of 10, 15, 20 and 30% is satisfactory (TB5-1401/505/II). The T113E1 (TB5-1401/505/II) successfully ascended a 37% slope at 1.22 mph at 9200 feet elevation.

B. Cooling

	115°F (below 3000 ft)	125°F (below 3000 ft)
1. Engineering cooling	Satisfactory	Generally satisfactory
2. Road load cooling	Generally satisfactory (rating questioned)	Generally satisfactory
3. Cross country	Satisfactory	Satisfactory

TB5-1401/505/II (T113E1) states that this vehicle's cooling characteristics and performance at 115°F ambient temperature are generally satisfactory at higher altitudes (9200 ft).

C. Vapor Lock

Characteristics were evaluated on early T113 and T113E1 vehicles and proved satisfactory. No vapor lock tendencies were encountered at altitudes of 5720 and 9270 feet (DPS/IT-5175/I -M113 Preproduction Model).

D. Endurance

All endurance tests of the T113E1 (TB5-1401/505/II) and Preproduction M113 (DPS/IT-5175/I) proved satisfactory.

E. Pertinent Physical Characteristics

1.	Ground clearance	Floor plate - 16" Final drive housing - 14"
2.	Ground pressure	7.1 psi

F. Pertinent Performance Factors

1.	Trench crossing	69"
2.	Vertical wall	24"
3.	Fording depth	Amphibious

APPENDIX C

SUMMARIES OF TEST REPORTS ON DESERT EVALUATIONS OF SELECTED VEHICLES

TANK, COMBAT, 90MM GUN, M48

REPORT TT2-760/1

1. Summarized results of full throttle cooling tests

Range	Vehicle Speed	Engine Speed	Ambient Temp.	Max. Cyl. Head Temp.	Engine Oil	Transmission Oil
Low	2.1	2315	107	484	220	305
Low	10.2	2800	103	512	234	262
Low*	10.2	2800	104	516	237	265
High	5.7	2335	106	487	227	309
High+	5.7	2335	104	488	233	311
High*	5.7	2300	93	480	217	302
High	5.0	2800	86	468	207	312

*Auxiliary engine operating
+Gun turned to front of vehicle

2. Vapor Lock Tests

Vehicle completed a five-hour run on fuel 0 2 psi rvp above Ordnance Specifications in an ambient of 105°F. Tests were conducted in Vapor Lock Gulch.

3. Mobility

Vehicle able to negotiate cross-country sand dunes course satisfactorily. On sand slopes over 40%, track slippage occurred

4. Miscellaneous

The main engine air cleaners when used in a dusty environment must be cleaned every four hours

5. Courses Traversed

Level dynamometer course

Vapor Lock Gulch

California sand dunes

REPORT TT1-671A/1 (Test of AV-1790-7 engines, installed in in M48 tanks)

1. Courses over Which Operated

a. "Break-in course"

b. Track sand course

c. Muggin's Mesa (track dust course)

2. Dust Course Results

a. Air cleaner failures resulted in serious damage to two test engines.

b. Numerous oil cooler failures occurred during test

c Throttle linkages gave continuous trouble

REPORT TB5-1401/112

1. Summary of full throttle cooling tests

Range	See Note	Vehicle Speed	Engine Speed	Ambient	Max. Cyl. Head	Temperatures Eng. Oil	Temperatures Trans. Oil
Low	1	10.9	2800	97	495	231	263
Low	1, 2, 3	10.9	2800	97	505	241	268
Low	4	10.9	2800	107	509	237	271
Low	2, 3, 4	10 9	2800	107	513	245	279
High	1	5 8	2355	98	495	217	301
High	4	5 8	2355	94	478	209	293
High	2, 4	5.8	2300	97	471	214	291
High	1	14.8	2300	99	495	215	239
High	4	14.8	2300	107	481	219	238

1 W/standard muffler
2 Auxiliary engine-generator operating
3 Slight running vapor lock during acceleration following this run
4 W/pancake mufflers

2. Road Load Cooling Tests

Engine speed (rpm)	2800	2400	2000
Road speed (mph)	30	21	17
Ambient temp. (°F)	92	100	105
Max cyl. head (°F)	435	407	406
Engine oil (°F)	219	207	204
Trans. oil (°F)	254	233	221

3. Cross-Country Cooling

Average engine speed (rpm)	2550
Average road speed (mph)	9
Max. cyl head (°F)	460
Engine oil (°F)	238
Trans oil (°F)	260

Mobility

1. Test Courses

a. Level, smooth hard surface

b. "Varied desert terrains"

TB-1401/195 (M48 TANK)

Dust

Dust collects on internal optical surfaces of Periscope M20A1.

Results

Cylinder heads, on the main engine, will overheat, and the main engine oil temperatures will be borderline at an ambient of 125°F.

The auxiliary generator will not successfully operate in an ambient of 125°F because of vapor lock and high cylinder head temperature.

None of the mufflers tested are satisfactory from a torching standpoint.

The modified fuel system, with the relocated fuel filter, for the main engine operated satisfactorily during vapor lock tests and would operate satisfactorily at 125°F temperatures using MIL-G-3056 specification fuel.

Full throttle cooling and vapor lock tests were constructed on the dynamometers course.

Road load cooling test was operated on smooth, hard surface.

Fire control was operated and tested on level and hilly cross-country courses. Also, endurance tests were evaluated for these same courses.

Test Mileage: 1408

Hard surface - 766
Cross country - 361
Hill cross country - 281

The M48 will not cool satisfactorily above an ambient of 100°F in the low range, full throttle condition. The limiting factors will be the excessive cylinder head temperatures in the No. 4 and No. 6 cylinders of the left bank and No. 3 cylinder of the right bank of the engine.

Vapor Lock Characteristics

The main engine operated without failure due to vapor lock and, although the fuel pressure to and at the carburetor reached as low as 0 5 psi, no malfunction of the engine was observed.

TB5-1401/216

The M48 operated in extreme dust conditions encountered on Muggin's Mesa dust course. Dust leaked into engine. No report of how the dust affected engine performance.

TB5-1401/357

The plastic fuel cells on the M48 failed immediately after installation and under static test during the pretesting phase.

TB5-1401/284

Of four plastic fuel cells tested on the M48, two failed upon being installed; the other two lasted 353 miles then failed. Repairs to the tanks that failed were not possible.

M274 (MECHANICAL MULE) CARRIER, LIGHT WEAPONS, INFANTRY, 1/2-TON, 4 X 4

Max. rated load, 1000 lb

Max. allowable cylinder head temp. 525°F

Max. allowable engine oil temp. 270°F

REPORT IT-5033/1 APG

Vehicle was subjected to various engineering tests and was operated over the following types of terrain (the ambient temperatures and grades are not stated).

Pavement
Gravel
Level cross country
Hilly cross country
Marsh and swamp

REPORT IT-5033/2 APG

Engineering test similar to the preceding. Operation over the following:

Pavement
Gravel
Level cross country
Hilly cross country
Marsh and swamp

Sustained speeds on the following slopes, type of surface, distance, or ambient temperature not stated

5° Slope - 25.5 mph
10° Slope - 16.0 mph
15° Slope - 12.5 mph
20° Slope - 10.0 mph
30° Slope - 7.5 mph
40° Slope - 6.0 mph

"Maximum sustained vehicle speeds not determined on 50% and 60% slopes due to engine malfunction."

"Operation on longitudinal slopes up to 60% and side slopes up to 40% was normal."

Temperatures at Various Loads. Temperatures not stabilized; tests stopped to prevent damage to engine. Type of road surface and slope not given.

	Road Load	Part Load	Full Load			Full Load with Modified Cooler Shroud
Operating time, min	45	35	15	20	20	25
Gear	H-3	H-1	H-2	H-2	H-2	H-2
Engine speed, rpm	4500	2400	2400	3400	4000	2400
Road speed, mph	26.0	4.5	7.9	11.3	13.3	7.9
DB pull, lb	-	550	470	400	320	450
No 2 cyl head, °F	423	466	505	503	502	506
Engine oil from cooler, °F	235	250	297	285	280	288
Ambient temp., °F	85	80.1	80.8	84.9	86.2	89
Wind speed (mph) & dir.	6-SSE	10-NW	11-SSW	8-SW	10-SW	7-SW

REPORT IT-5121/2 APG

Similar to preceding. Operations are the following:

Gravel	Murson
Hilly cross country	Churchville
Level cross country	Perryman
Marsh and swamp	Murson

Fording depth - 18"

Cylinder head and crankcase oil temperatures given for three vehicles for idle, road load and full load, but ambient temperatures omitted

REPORT TB5-1401/458; IT-5068/2 - Yuma

Test included cooling, vapor lock, dust, fording, mobility, endurance.

Cooling

Borderline under the most severe road load and c.c. conditions

Full load, full throttle in 95°F cylinder head and oil temperature exceeded max. after 12 min operation.

Part throttle, 925 lb DB pull - at 1 mph in reverse on simulated 60% grade, oil temperature exceeded max. at 104°F ambient.

Road load cooling on level pavement - cylinder head and oil temperature below max. at all ambients extrapolated to 125°F.

Part throttle - oil from cooler exceeds max. at 107° and 113°, extrapolated.

Towne's Pass, Engine speed 2700 - 4200 rpm, high gear range.

Elev.	Time	Amb.	Cyl.	Oil	Max. Permissible Cyl. Head Temp. Reached at Following Ambient (Extrapolated)
0	1145		446	220	127
1000	1235	102	500	232	127
2000	1246	97	495	239	127
3000	1255	95	500	240	120
4000	1303	91	511	242	104

Daylight Pass

0	-	-	470	
1000	-	-	515	
2000	-	-	525	No ambient stated
3000	-	-	515	
4000	-	-	505	

Overheated in deep soft sand, slopes. Oil sump temperature reached 250° at 98°F ambient - extrapolated = 270°F at 118°F.

Mobility

Operated are the following

*Prepared sand slopes - 10%
15%
20%

* Could not traverse any freshly plowed slope at any tire pressure with appreciable speed

	Average Speed
Sand dynamometer course	
Paved slope	60% - tendency to pitch - considered unsafe
Sand plains	9.25
Dry wash	3.79
Desert pavement	18.50
Stony, rocky desert	2.40
Hummocky sand	5.43

Vapor Lock - No trouble at 115° simulated ambient.

Fording - 18"

Endurance - various deficiencies, not attributable to environment.

M35 TRUCK, CARGO, 2-1/2-TON, 6 X 6

TB5-1401/213 (M35)

% Slope	Payload - Empty	Payload, 5000 lb	5000- and 7900-lb Towed Load
10	12 lb	10 lb	5 lb
15	6 lb	10 lb	5 lb
20	2 lb	5 lb	Not negotiable

The slope gradeability tests were run on disc harrowed sand slopes and indicated that the vehicles would perform satisfactorily within reasonable limits, with the rated cross-country payload. The practicable tire pressures with respect to grade and load factors are as above.

TB5-1401/27 (M34 & M35)

The M35, with dual tires, will operate satisfactorily over the common desert terrain, but is limited to carefully reconnoitered trails or prepared roadways in the sand dune areas.

The M35 could not negotiate the 20% prepared sand slope with any payload.

TB5-1401/276

The six-bladed fan did result in a cooling improvement over the five-bladed fan. The coolant differential exceeded the 95° specification in L-1 gear at full torque engine speed (1400 rpm), and the engine oil temperature in the galley was borderline at maximum horsepower engine speed (3400 rpm). Transmission oil temperature is critical during operation at 2400 rpm and higher. The engine would not properly cool under conditions of high ambient temperatures. Modifications were made to the engine and cooling systems which improved the vehicle's cooling characteristics; however, they still did not meet Ordnance requirements.

TB5-1401/213

The standard vehicle equipped with the experimental oil cooler provided the best over-all cooling characteristics; however, coolant differential and engine oil temperatures were still borderline during the more severe operating conditions and would exceed the cooling specifications at 125°F.

Gear	rpm	Ambient Temperatures	Oil Gallery Temperatures	Coolant Temperatures
H-2	2400	88° - 91°F	228°F	180°F
H-2	2400	91° - 96°F	223°F	181°F
H-2	1400	96° - 100°F	215°F	185°F

TB5-1401/78

Incipient vapor lock encountered under severe operating conditions using fuel adjusted to 8 psi rvp at 125°F.

DESERT TEST DATA - M113 (Carrier, Personnel, Full-Tracked)

TB5-1401/400

T113 (Code C Air Cooled Engine)

The performance of this engine-vehicle combination met environmental criteria (operation in an ambient temperature of 115°F) projected over 90% of the vehicle speed range and would have also been satisfactory at 125°F.

Average Swim Speed - 3.86 mph

Prepared Sand Slopes

Gear Range	Slope Gradient 10%	15%	20%
1st	--	6.51 mph	7 20 mph
2nd	9.12	8.55	5.82
3rd	7.02	5.16	4 21
4th	4.72	2.88	No-Go*

*Lack of power

Operation in California Sand Dunes was unsuccessful, as the vehicle was frequently immobilized because of track suspension inadequacies.

Characteristic Sheet for T113 Carrier (TB5-1401/400, p 5)

Performance:

Max. speed 40 mph
Max. grade 60%; Side. 30%
Max trench. 66"
Max. vert. wall 18"
Cruising range 200 miles
Max. ford depth Unlimited

Ground clearance is 15"
Ground pressure (psi) 6.7

TB5-1401/505 Part 2 Environmental Test (1958-59) (T113EI)

Mobility Tests - Prepared Course

	T113El			
Percent grade	10	15	20	30
Avg. speed, mph	8.7	5.9	5.7	2.6
Gear range	3LV	3-Conv.	1LV	1 Conv.

Maximum speed at sea level was 36 8 mph and 28.0 mph at 9000 ft altitude. General performance and functioning were satisfactory up to 11,000 ft altitude.

The vehicle successfully ascended a 37 percent slope at 1.22 mph at 9200 ft elevation but could not ascend a 40 percent slope.

Cooling characteristics at 115°F ambient temperatures and performance of this vehicle at higher altitude are generally satisfactory.

Mobility and dust characteristics of the T113El carrier were satisfactory for summer operation in the desert.

Courses - Yuma

Paved
Gravel
Level cross country
Hilly cross country
Dust
Sand

TB5-1401/400, p 44

Swamp. The T117 (similar to the M113) was tested in an area along the Colorado River covered with swamp grass and occasional small brush; the ground (alluvial silt) was soft and damp, saturated but not inundated by water The vehicle was able to maintain speed (est 10 mph) for approximately 150 yards before becoming immobilized. Once speed is lost, continued movement of tracks results in high-centering of the vehicle and immobilization from hull-ground contact. It was unable to extricate itself

TB5-1401/505 Part 1 Environmental Test (1958-59) (T113El)

Standard Slope Performance The T113El (2400-lb GVW-185 hp) ascended a 60% slope without difficulty. The service brakes would not hold the vehicle

stationary for more than 12 seconds when ascending - **braking was satisfactory** while descending.

Obstacles: **Bridging vertical wall obstacles up to 24" in forward; only 18"** in reverse.

Test results indicate the vehicle will cool satisfactorily at ambient temperatures of 115°F. No vapor lock or hot fuel handling difficulties during starting or full throttle operation at 115°F.

Sand dune mobility - track slip prevented ascent of slopes over 30 percent

Courses - Desert

- Paved
- Tank gravel course
- Tank level course
- Country course
- Tank hill course

DPS/IT-5175/1 (Preproduction Pilot M113)

Slope Performance

Speed, %	5	10	15	20	30	40	50	60
Sustained Speed(mph)	22.3	14.7	11.4	8.4	7.3	3.8	3.0	2.4
Transverse	5th	3rd	2nd	2nd	1st	1st	1st	1st
Speed range	LU	LU	LU	LU	LU	Conv	Conv	Conv

Full-Load Cooling Full-load, full-throttle cooling data gathered in ambient temperatures of 95°F to 109°F and extrapolated to 115°F show that the vehicle power train components will cool satisfactorily

Road-Load Cooling ---- engine oil, differential oil and engine coolant temperatures will be marginal at 115°F under maximum speed conditions.

Altitude Vehicle performance at altitudes of 5720 and 9270 feet was generally satisfactory - no vapor lock tendencies encountered

APPENDIX D

DESERT ENVANAL CHARTS ON SELECTED VEHICLES

EQUIPMENT TESTED: TANK, COMBAT, FULL-TRACKED, 90MM GUN, M48 (T48)

REPT. REF.	REPORT NUMBER	LOCATION AND YEAR OF TEST	EQUIPMENT MODIFICATIONS INCORPORATED INTO TEST ITEM	SUPPORTING EQUIPMENT AND/OR LOADS UTILIZED
•	TT2-760/1 (U)	YUMA TEST STATION SUMMER 1952	T48 TANK.	COMBAT LOADED.
-●-	TT1-871A/1 (U)	YUMA TEST STATION SUMMER 1953	THE ENGINE OF TWO VEHICLES EQUIPPED WITH CHROMIUM PLATED RINGS. THE ENGINE OF ONE VEHICLE EQUIPPED WITH CAST IRON OIL CONTROL RINGS.	COMBAT LOADED.
⌿	TB5-1401/112 (U)	YUMA TEST STATION SUMMER 1953	PAN CAKE MUFFLERS; 300-AMPERE MAIN ENGINE GENERATOR; AUXILIARY ENGINE GENERATOR UNIT DUCTED TO DRAW COOLING AIR FROM TURRET. (T48 VEHICLE)	COMBAT LOADED.
••	TB5-1401/195 (U)	YUMA TEST STATION SUMMER 1954	MAIN ENGINE FUEL SYSTEM MODIFIED TO INCORPORATE TWO FUEL FILTERS; CARBURETOR DEGASSER WITH 17" HG CLOSING POINT; EXPERIMENTAL FIRESTONE AND "HOLLYWOOD" TYPE MUFFLERS; FUEL BY-PASS MODIFICATION FOR AUXILIARY ENGINE; FLUID MIL-O-[illegible] AND FLUID OH-3-[illegible] FOR FIRE CONTROL SYSTEM.	COMBAT LOADED. APT T[illegible] AND HE M71A[illegible] AMMUNITION.
-●●-	TB5-1401/216 (U)	YUMA TEST STATION SUMMER 1954	OE30 OIL IN ENGINE CRANKCASE AND AIR CLEANER IN LIEU OF OEM AS SPECIFIED IN LUBRICANT MANUAL; CODE C-4 DRY-TYPE AIR CLEANER PLUS THREE WET-TYPE, MILITARY APPROVED CLEANERS; MECHANICAL TYPE OIL COOLER FANS AN AV-1790-[illegible] IGNITION BREATHER SYSTEM HARNESS; AN AV-1790-7 ENGINE.	TWO PAIR OF FENDER MOUNTED ABSOLUTE FILTERS FOR CONTROL.
⌿⌿	DA/CL R3062 (U)	DETROIT ARSENAL SUMMER 1954	PAN CAKE MUFFLERS; VARIOUS TYPES OF COOLING BAFFLES.	COMBAT LOADED.
//	TB5-1401/284 (U) TB5-1401/357 (U)	YUMA TEST STATION SUMMER 1955, 1956	REINFORCED EPOXY-RESIN FUEL CELLS.	

LINE ITEM NO.: 444061	STOCK NO.: 2350-736 4202	TYPE CLASSIFICATION: STD-B	OTCM REFERENCE: 34795-C; 35619-U; 35667-B; 36041-U

SUMMARY OF PERFORMANCE:

Cooling characteristics are satisfactory at 107 degrees, marginal at 115 degrees, and critical at 125 degrees. Mobility characteristics satisfactory in all terrains over which tested. Vapor handling characteristics are satisfactory provided modifications in 1954 tests are made. Many proposed modifications to vehicle have been tested for desert endurance and functioning. Examples are chrome piston rings, experimental mufflers, experimental air cleaner, plastic fuel cells. (See functioning ratings for more detailed description of results of modification changes.) Engine cooling and vapor handling characteristics of auxiliary engine are satisfactory if cooling air is drawn from turret, otherwise overheating and vapor lock will result. Endurance and functioning of vehicle is affected by dust operation. See rating sheet for M48A tank for water operation evaluation.

TEST / ENVIRONMENTAL FACTORS

Environmental factors: A PAVED SURFACES; B PREP. GRAVEL SURFACES; C HARD UNPREP. SURFACES; D STONY OR ROCKY GROUND; E GRAVEL, LOOSE; F ALLUVIAL FANS (SAND, SILT, GRAVEL AND ROCKS); G DESERT PAVEMENT (SAND, SILT, AND GRAVEL); H DUNE SAND; I SAND PLAIN (LOOSE SAND); J PREP. SAND SLOPE—10%; K PREP. SAND SLOPE—15%; L PREP. SAND SLOPE—20%; M WATER; N TEMPERATURE (TEST AMBIENT); O TEMPERATURE (115 F—BELOW 3000 FT. ALT.); P TEMPERATURE (125 F—BELOW 3000 FT. ALT.); Q SOLAR RADIATION; R DUST (AIR BORNE); S BLOWING SAND; T RAINFALL; U HILLY OR MOUNTAINOUS; V MUD; W VEGETATION; X; Y; Z

TEST NO.	TYPE	NO. OF ITEMS	REPT. REF.	EXTENT	AMB. TEMP. MIN.	AMB. TEMP. MAX.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	ENG COOL'NG	1	•		86	107	1													[illegible]	[illegible]	[illegible]										
2	VP LK	1	•			105					1									[illegible]	[illegible]	[illegible]										
3	M'B'TY	1	•	[illegible] MI			1					1	1	1																		
4	FUNCTION'G	1	•	[illegible] MI								[illegible]	[illegible]							[illegible]				[illegible]								
5	END'NCE	1	•	[illegible] MI			[illegible]					[illegible]	[illegible]							[illegible]												
6	FUNCTION'G CAST IRON RINGS	1	-●-	1568 MI		114	[illegible]					[illegible]	[illegible]							[illegible]	[illegible]	[illegible]		[illegible]								
7	FUNCTION'G CHROME RINGS	2	-●-	3414 MI		110	1								3					3	[illegible]	[illegible]		[illegible]								
8	END'NCE CAST IRON RINGS	1	-●-	1568 MI			[illegible]													[illegible]				[illegible]								
9	END'NCE CHROME RINGS	2	-●-	3414 MI			1													3				[illegible]								
10	ENG COOL'NG	1	⌿		94	107	1													1	[illegible]	[illegible]										
11	RD COOL'NG	1	⌿		81	103	1													1	[illegible]	[illegible]										
12	VP LK	1	⌿		94	104	1													[illegible]	[illegible]	[illegible]										
13	M'B'TY	1	⌿	[illegible] MI					1	1		1	1																			
14	FUNCTION'G	1	⌿	307 MI						3		[illegible]	[illegible]											[illegible]								
15	END'NCE	1	⌿	307 MI			1					1	1							1												
16	ENG COOL'NG AUXILIARY GENERATOR	1	⌿		81	109														1	[illegible]	[illegible]										
17	VP LK AUXILIARY GENERATOR	1	⌿																	1	1	1										
18	ENG COOL'NG EXP MUFFLER	1	••		90	107	1													[illegible]	[illegible]	[illegible]										
19	ENG COOL'NG STD MUFFLER	1	••		90	107	1													1	[illegible]	[illegible]										
20	VP LK MODIFIED FUEL SYSTEM	1	••		[illegible]	[illegible]	1													1	1	1										
21	M'B'TY	1	••	[illegible] MI					1	1	1	1	1														1					
22	FUNCTION'G	1	••	[illegible] MI			1					[illegible]	[illegible]							1				[illegible]			1					
23	END'NCE	1	••	[illegible] MI			1					1	1														1					
24	FIRE CNTR'L	1	••									1	1							1				1								
25	VP LK AUXILIARY ENGINE	1	••		[illegible]	[illegible]														1	[illegible]	[illegible]										

TANK, COMBAT, FULL-TRACKED, 90MM GUN, M48 (T48)

TEST NO.	TYPE	NO. OF ITEMS	REPT. REF.	EXTENT	AMB. TEMP. MIN.	AMB. TEMP. MAX.	A PAVED SURFACES	B PREP. GRAVEL SURFACES	C HARD UNPREP. SURFACES	D STONY OR ROCKY GROUND	E GRAVEL, LOOSE	F ALLUVIAL FANS (SAND, SILT, GRAVEL AND ROCKS)	G DESERT PAVEMENT (SAND, SILT, AND GRAVEL)	H DUNE SAND	I SAND PLAIN (LOOSE SAND)	J PREP. SAND SLOPE—10%	K PREP. SAND SLOPE—15%	L PREP. SAND SLOPE—20%	M WATER	N TEMPERATURE (TEST AMBIENT)	O TEMPERATURE (115°F — BELOW 3000 FT. ALT.)	P TEMPERATURE (125°F — BELOW 3000 FT. ALT.)	Q SOLAR RADIATION	R DUST (AIR BORNE)	S BLOWING SAND	T RAINFALL	U HILLY OR MOUNTAINOUS	V MUD	W VEGETATION	X	Y	Z
26	FUNCTION'G	1	[illegible]	1147 MI								3	3							1				3								
27	END'NCE	1	[illegible]	1147 MI								3	3							3				3								
28	ENG COOL'NG	1	//				1													1												
29	FUNCTION'G PLASTIC FUEL CELLS	1	//																													
	SUMMARY LOWEST CURRENT RATING						3		1	3	1	3	3	1	3					5				3			3					

NOTES

NICKNAMED "PATTON 48"

1	N, O, P	ENGINE OIL TEMPERATURE MAY EXCEED (SLIGHTLY) THE ALLOWABLE LIMIT AT MAXIMUM SPEED (2800 RPM) IN AN AMBIENT OF 125 DEGREES. MINIMUM SPEED LIMITED TO 2.1 MPH IN LOW GEAR AT AMBIENT OF 107 DEGREES BY TRANSMISSION OIL TEMPERATURE.
2	N, O, P	INCIPIENT VAPOR LOCK ENCOUNTERED ON FUEL ADJUSTED TO 8.2 PSI RVP AT 125 DEGREES. RATING INVALIDATED BY LATER TESTS (SEE LINE 25).
4	ALL	AUXILIARY GENERATOR UNIT DOES NOT DEVELOP RATED POWER. SHIFTING DIFFICULT. DUST AND SAND CAUSE STICKING OF THROTTLE LINKAGE. RATINGS INVALIDATED BY DESIGN CHANGES.
5	ALL	ONE ROAD WHEEL ARM FAILURE. RATING QUESTIONED BECAUSE FAILURE WAS BELIEVED TO BE RESULT OF FAULTY MATERIAL RATHER THAN ENVIRONMENTAL STRESS.
6, 8	ALL	RATINGS INVALIDATED; CAST IRON RINGS REPLACED WITH CHROME RINGS IN PRODUCTION ITEM.
6, 7, 8, 9	R	DEFICIENCIES OF THE INDUCTION SYSTEM, BREATHER SYSTEM, AND FILLER AND DIPSTICK CAP ALLOW SUFFICIENT DUST TO SERIOUSLY LOWER ENGINE DURABILITY. RATINGS QUESTIONED BECAUSE MODIFICATION IMPROVEMENTS.
6	I, N, O, P	MAXIMUM CYLINDER HEAD TEMPERATURE STABILIZED AT 523 DEGREES IN 114 DEGREES AMBIENT ON CROSS-COUNTRY COURSE.
7	I, N, O, P	MAXIMUM CYLINDER HEAD TEMPERATURE STABILIZED AT 545 DEGREES IN 110 DEGREES AMBIENT ON SAND COURSE AS COMPARED WITH 485 DEGREES AT 106 DEGREES ON DYNAMOMETER COURSE.
8, 9	N, R	"CHROME-PLATED OIL CONTROL RINGS APPEAR TO INCREASE ENGINE LIFE.
10, 11	N, O, P	COOLED SATISFACTORILY AT TEMPERATURE OF TEST; HOWEVER, DATA INDICATES THAT CYLINDER HEAD AND ENGINE OIL TEMPERATURE WILL SLIGHTLY EXCEED SPECIFICATIONS AT 125 DEGREES.
12	N, O, P	VAPOR LOCK EXPERIENCED WITH FUEL ADJUSTED TO 8 PSI RVP AT 125 DEGREES. INCIPIENT LOCK ENCOUNTERED ON FUEL OF 8 PSI RVP AT 100 DEGREES. (RESULTS ARE REPORTED IN TB1-1401/100). RATINGS INVALIDATED BY LATER TESTS (SEE LINE 25).
14	D, F, G, R	SHIFTING DIFFICULT, HEAVY PRESSURE REQUIRED. FREQUENT CLEANING REQUIRED TO PREVENT DUST AND SAND FROM BINDING THROTTLE LINKAGE. TRACK WEAR HIGH. RATINGS QUESTIONED. TEST ENGINEER STATES THAT DEFICIENCIES HAVE BEEN SUBSTANTIALLY IMPROVED, EXCEPT FOR TRACK WEAR ON STONY OR ROCKY GROUND.
15	F, N	ONE SHOCK ABSORBER AND ONE GENERATOR RELAY FAILURE.
16	N, O, P	COOLED SATISFACTORILY AT TEMPERATURE OF TEST. DATA INDICATES OIL TEMPERATURE WOULD EXCEED SPECIFICATIONS AT 125 DEGREES AMBIENT.
18, 19	N, O, P	ENGINE OIL AND CYLINDER HEAD TEMPERATURES ARE BORDERLINE UNDER SOME CONDITIONS AT AMBIENT OF TEST AND WOULD EXCEED THE SPECIFICATIONS AT 125 DEGREES AMBIENT. THESE TEMPERATURES WERE HIGHER WITH BOTH EXPERIMENTAL MUFFLERS THAN WITH THE STANDARD MUFFLER. TRANSMISSION TEMPERATURES WERE SLIGHTLY REDUCED.
18	N, O, P	RATINGS INVALIDATED BECAUSE EXPERIMENTAL MUFFLERS WERE NOT INCORPORATED INTO PRODUCTION ITEM.
20	N, O, P	FUEL ADJUSTED TO EQUIVALENT OF 8 PSI RVP AT 125 DEGREES.
22	N	TORCHING OF STANDARD AND EXPERIMENTAL MUFFLERS AT HIGH LEVEL. FIRESTONE MUFFLER SLIGHTLY BETTER. NOISE LEVEL OF HOLLYWOOD TYPE MUFFLER WAS HIGH.
22	A, F, G, U	FRONT RIGHT AND LEFT ROADWHEEL ARM DESIGN PERMIT ROADWHEEL INTERFERENCE WITH THE ROAD ARM SUPPORT BRACKETS OF THE WHEEL RESULTING IN NUMEROUS BEARING AND SEAL FAILURES.
22	F, G, R	CONTROL LINKAGE STICKAGE IS CONSTANT PROBLEM IN DUSTY CONDITIONS. RATINGS QUESTIONED BECAUSE OF DESIGN IMPROVEMENTS. OTA STATES PROBLEM STILL EXISTS BUT IS OF MINOR MAGNITUDE.
23	A, F, G, U	NUMEROUS FAILURES OF FRONT ROAD WHEELS AND THEIR COMPONENTS.
24	F, G, N, R	DUST ACCUMULATION ON M20A1 PERISCOPE UNITY POWER PRISM REQUIRES FREQUENT CLEANING. TIME REQUIRED TO ENGAGE A STATIONARY TARGET DOES NOT MEET SPECIFICATION REQUIREMENT OF 5 SECONDS FOR 10 MILS ELEVATION AND 25 AZIMUTH LAY-OFF.
24	N	THERMAL CHANGES CAUSE A MEASURABLE ERROR IN THE ALIGNMENT OF THE TELESCOPE, PERISCOPE, AND RANGEFINDER (T156E1, M20A1, AND T46E1, RESPECTIVELY). FLUID OH-2-798 CHARACTERISTICS SLIGHTLY BETTER THAN FLUID MIL-0-5606.
25	N	COMPLETE VAPOR LOCK WITHIN 7 MINUTES OPERATION AT FULL LOAD. BY-PASS MODIFICATION HAD NO APPARENT EFFECT.
26	ALL	DUST LEAKAGE WAS PRESENT THROUGHOUT THE TEST FROM THE HOSE CONNECTIONS OF THE AIR CLEANER TO CARBURETOR DUCTS. DUST LEAKAGE AT OTHER LOCATIONS WERE DUE TO LOOSE NUTS AND FITTINGS.
27	ALL	THE LOW VISCOSITY OF THE ENGINE OIL (OE 30) WAS THE PRINCIPLE FACTOR OF " GREATER THAN NORMAL " ENGINE WEAR.
28	ALL	"COMPARISON OF THE COOLING CHARACTERISTICS OF THE VEHICLE EQUIPPED WITH THE STANDARD MUFFLER OR EQUIPPED WITH PAN CAKE MUFFLERS INDICATE THE ARRANGEMENTS WERE SUBSTANTIALLY EQUAL. DURING TEST RUNS WITH EACH TYPE OF MUFFLER, THE CORRECTED ENGINE AND TRANSMISSION TEMPERATURES EXCEEDED CRITICAL VALUES FOR THE MAJORITY OF TEST RUNS."
29	N	THE CELLS, AS SUBMITTED, ARE UNSATISFACTORY. LEAKS ARE CAUSED BY SOFT BONDING AGENTS, LAYERS OF MATERIALS NOT SUFFICIENTLY BONDED TOGETHER, AND INSUFFICIENT EDGE DISTANCE FOR FITTINGS AT LAPS AND EDGES. (SIMILAR RESULTS SHOWN DURING BOTH TESTS.) RATING INVALIDATED BECAUSE CELLS WERE NOT INCORPORATED INTO PRODUCTION ITEM.

EQUIPMENT TESTED: CARRIER, LIGHT WEAPONS, INFANTRY, 1/2-TON, 4X4, M274 (XM274)

REPT. REF.	REPORT NUMBER	LOCATION AND YEAR OF TEST	EQUIPMENT MODIFICATIONS INCORPORATED INTO TEST ITEM	SUPPORTING EQUIPMENT AND/OR LOADS UTILIZED
•	TB5-1401/458 (U)	YUMA TEST STATION SUMMER, 1957, 1958	ONE PRE-PRODUCTION VEHICLE MODIFIED TO BE NEARLY THE SAME AS A CURRENT PRODUCTION MODEL; ONE REGULAR PRODUCTION VEHICLE.	500 LBS PAYLOAD

LINE ITEM NO.: 405215	STOCK NO.: 2320-049-4804	TYPE CLASSIFICATION: STD-A	OTCM REFERENCE: 35036-R; 36841-U

SUMMARY OF PERFORMANCE:

Vehicle will cool satisfactorily under most roadload and cross-country conditions to 115 degrees; however, during operation in soft sand or steep hills, engine oil temperatures will exceed specification at 100 degrees. Full-throttle cooling has been unsatisfactory in all test ambients (95-104 degrees). Vapor handling characteristics are satisfactory to 125 degrees. Vehicle has satisfactory mobility characteristics; however, caution must be taken during dune sand (or similar terrain) operation to prevent bead slippage if the tires have been deflated for better traction. Several endurance failures, mostly minor, have occurred, but cause is uncertain. APG states that contractor has made substantial modifications on vehicle to correct cooling and endurance deficiencies. No information available as to test performance with modifications.

TEST / ENVIRONMENTAL FACTORS

TEST NO.	TYPE	NO. OF ITEMS	REPT. REF.	EXTENT	AMB. TEMP. MIN.	AMB. TEMP. MAX.	A PAVED SURFACES	B PREP. GRAVEL SURFACES	C HARD UNPREP. SURFACES	D STONY OR ROCKY GROUND	E GRAVEL, LOOSE	F ALLUVIAL FANS (SAND, SILT, GRAVEL AND ROCKS)	G DESERT PAVEMENT (SAND, SILT AND GRAVEL)	H DUNE SAND	I SAND PLAIN (LOOSE SAND)	J PREP. SAND SLOPE—10%	K PREP. SAND SLOPE—15%	L PREP. SAND SLOPE—20%	M WATER	N TEMPERATURE TEST AMBIENT	O TEMPERATURE (115 F—BELOW 3000 FT. ALT.)	P TEMPERATURE (125 F—BELOW 3000 FT. ALT.)	Q SOLAR RADIATION	R DUST (AIR BORNE)	S BLOWING SAND	T RAINFALL	U HILLY OR MOUNTAINOUS	V MUD	W VEGETATION	X ALTITUDE	Y	Z
1	ENG COOL'NG	1	•		95	104	1													5	5	5										
2	RD COOL'NG	1	•		80	104	1		1		1	1	1	3						1	1	4					3					
3	VP LK	1	•		102	104					1									1	1	1										
4	M'B'TY	1	•				1	1	1		1	1	1	3	1												3					
5	END'NCE	1	•				3	3	3		3	3	3	1	3					1							1					
	SUMMARY LOWEST CURRENT RATING						3	3	3		3	3	3	3	3					5	5	5					3					

NOTES

1	N, O, P	UNDER FULL-THROTTLE CONDITIONS, THE ENGINE OVERHEATED BEFORE TEMPERATURE STABILIZATION OCCURRED IN ALL PREVAILING AMBIENTS.
2	N, O	THE VEHICLE COOLED SATISFACTORILY UNDER ALL ROAD LOAD CONDITIONS.
2	H, N, O, P, U	WHEN DRAW BAR LOADING WAS APPLIED TO SIMULATE THE EFFECT OF A 60 PERCENT SLOPE, THE TEMPERATURE OF THE ENGINE OIL, WHILE OPERATING AT 1 MPH IN REVERSE, WAS 245 DEGREES AT AN AMBIENT AIR TEMPERATURE OF 80 DEGREES.
3	N, O, P	FUEL EQUIVALENT TO 9 PSI RVP AT 125 DEGREES.
4	H	VEHICLE EXHIBITED EQUAL OR BETTER MOBILITY THAN THE ESCORTING M38A1 TRUCK. A 6 PSI TIRE PRESSURE WAS FOUND TO PROVIDE THE BEST PERFORMANCE, BUT WAS TOO LOW TO AVOID BEAD SLIP, WHICH RESULTED IN VALVE STEM SEPARATION ON THREE TUBES DURING OPERATION OVER LEVEL AREAS WHERE THE SAND WAS MORE COMPACTED.
5	ALL	ENDURANCE FAILURES WERE: CARBURETOR FLOODING, VALVE SEAL SEPARATION, SCORED CYLINDER WALLS, GOVERNOR MALFUNCTION, TIRE CUTTING, SPARK PLUG FOULING, STEERING GEAR FAILURE, FAN BELT STRETCHING. RATING QUESTIONED BECAUSE OF UNCERTAINTY AS TO CAUSE. TEST ENGINEER FEELS THAT LEAKING OF SEALS WAS CAUSED BY OPERATION IN DUSTY ENVIRONMENT.

APG STATES THAT CONTRACTOR HAS MADE SUBSTANTIAL MODIFICATIONS ON VEHICLE TO CORRECT COOLING AND ENDURANCE DEFICIENCIES. NO INFORMATION AVAILABLE AS TO TEST PERFORMANCE WITH MODIFICATIONS.

EQUIPMENT TESTED: TRUCK, CARGO, 2 1/2–TON, 6X6, M35 (XM35)

REPT. REF.	REPORT NUMBER	LOCATION AND YEAR OF TEST	EQUIPMENT MODIFICATIONS INCORPORATED INTO TEST ITEM	SUPPORTING EQUIPMENT AND/OR LOADS UTILIZED
*	TB5-1401/27 (U)	YUMA AND DEATH VALLEY SUMMER, 1952	LATEST PRODUCTION TYPE OVER-RUNNING CLUTCHES INCORPORATING LARGER DIAMETER RACES AND LONGER SPRAY UNITS.	M104 TRAILER (3400 LB GROSS WEIGHT); CROSS-COUNTRY PAYLOAD, 5000 LBS HIGHWAY PAYLOAD, 10,000 LBS.
-⊖-	TB5-1401/78 (U)	YUMA AND DEATH VALLEY SUMMER, 1953	RADIATOR SHIELDS, SIX-BLADED FAN, 7 1/2 PSI RADIATOR CAP, HIGH CAPACITY OIL PUMP, OIL COOLER, ORDNANCE SUBMERGED ELECTRIC FUEL PUMPS.	22,500 LB AVERAGE GROSS WEIGHT 7,500 LB TOWED LOAD
≁	TB5-1401/213 (U)	YUMA AND DEATH VALLEY SUMMER, 1954	HIGH COMPRESSION ENGINE, WINCH BUMPER-SIMULATED, EXPERIMENTAL OIL COOLER, RADIATOR BAFFLES, ORDNANCE SUBMERGED ELECTRIC FUEL PUMP, VENTED GAS CAP (MANUAL), 4 PERCENT OVER-RUNNING CLUTCH.	5,000 LB PAYLOAD 7,500 LB TOWED LOAD
**	TB5-1401/276 (U)	YUMA TEST STATION SUMMER, 1955	INCREASED CAPACITY RADIATOR (18 QT) WITH 3 1/2 INCH CASE, SIX-BLADE FAN AND FIVE-BLADE FAN; OIL COOLER; ELIMINATION OF SUPPORT BRACKET AND INSTALLATION OF A "SPACER" ON THE REAR EXHAUST PIPE MOUNTING BRACKET CAST GENERATOR BRACKET; NEOPRENE VIBRATION DAMPER IN PLACE OF BUTYL VIBRATION DAMPER; AND ORD SUB. ELECTRIC FUEL PUMP.	

LINE ITEM NO.: 460110 460141 | STOCK NO.: 2320-835-8463 2320-835-8464 | TYPE CLASSIFICATION: STD–A | OTCM REFERENCE: 38241–U; 38195–U; 35813–U; 38644–U; 34752–R; 38641–U

SUMMARY OF PERFORMANCE:

Vehicle performs satisfactorily on all level, firm terrains. Depending upon load conditions, operation in combination of sand and slopes will range from marginal to unsatisfactory. Functioning and endurance characteristics are satisfactory under all environments. Cooling characteristics, while unsatisfactory in ambients above 100 degrees with the standard vehicle can be improved to marginal performance in 125 degrees by using six-blade fans, and oil coolers. Vapor handling characteristics of vehicle are satisfactory if a submerged electric fuel pump is used. Octane requirements for a high compression engine tested in the vehicle in 1954 were 92.5 (knock-in, knock-out method) under full load conditions. (This vehicle is same as M34 truck except for tire mounting. This vehicle carries 9:00 x 20 dual tires; M34 vehicle mounts 11:00 x 20 single tires.)

TEST — ENVIRONMENTAL FACTORS

TEST NO.	TYPE	NO. OF ITEMS	REPT. REF.	EXTENT	AMB. TEMP. MIN.	AMB. TEMP. MAX.	A PAVED SURFACES	B PREP. GRAVEL SURFACES	C HARD UNPREP. SURFACES	D STONY OR ROCKY GROUND	E GRAVEL, LOOSE	F ALLUVIAL FANS (SAND, SILT, GRAVEL AND ROCKS)	G DESERT PAVEMENT (SAND, SILT, AND GRAVEL)	H DUNE SAND	I SAND PLAIN (LOOSE SAND)	J PREP. SAND SLOPE—10%	K PREP. SAND SLOPE—15%	L PREP. SAND SLOPE—20%	M WATER	N TEMPERATURE TEST AMBIENT	O TEMPERATURE (115 F — BELOW 2000 FT. ALT.)	P TEMPERATURE (125 F — BELOW 3000 FT. ALT.)	Q SOLAR RADIATION	R DUST (AIR BORNE)	S BLOWING SAND	T RAINFALL	U HILLY OR MOUNTAINOUS	V MUD	W VEGETATION	X ALTITUDE	Y	Z
1	M' B' TY NO LOAD	1	*									1	1																			
2	M' B' TY W/CC LOAD	1	*									1	1																			
3	M' B' TY W/HWY LOAD	1	*									1	1	4		2	3	5														
4	M' B' TY W/CC LOAD AND TOWED LOAD	1	*									1	1	5																		
5	FUNCTION' NG	2	*	13,000 MI EA		113	1	1	1			1	1	1	1	1	1	1		1							3			3		
6	END' NCE	2	*	5,000 MI EA		113	1	1	1			1	1	1	1	1	1	1		1							1			1		
7	ROAD COOL' NG	3	-⊖-		87	124	1																									
8	ROAD COOL' NG W/EXP COMPONENT	3	-⊖-	18,400 MI	77	124	1																									
9	VP LK STD FUEL PUMP	2	-⊖-		85	124	1													3	3	3										
10	VP LK SUB FUEL PUMP	1	-⊖-		85	124	1													1	1	1										
11	FUNCTION' NG	3	-⊖-		77	124	2													1	1						1			1		
12	END' NCE	3	-⊖-	18,400 MI	77	124	1													1	1						1			1		
13	ENG. COOL' NG STD ENGINE	1	≁		95	107	1																									
14	ENG. COOL' NG W/BAFFLES	1	≁		91	94	1																									
15	ENG. COOL' NG W/EXP OIL COOLER	1	≁		88	107	1																									
16	ENG. COOL' NG W/WINCH BUMPER OIL COOLER	1	≁		95	107	1																									
17	ROAD COOL' NG STD VEHICLE	1	≁		70	123	1													5	5											
18	ROAD COOL' NG W/OIL COOLER	1	≁		70	123	1													4	4											
19	OCT RT' NG HIGH COMP. ENG.	1	≁		71	100	1													4	4	4										
20	VP LK SUBMERGED FUEL PUMP AND VENTED CAP	1	≁		99	100	1													1	1	1										
21	VP LK SUBMERGED FUEL PUMP AND VENT CLOSED	1	≁		99	100	1													4	4	4										
22	M' B' TY EMPTY	1	≁													2	3	4														
23	M' B' TY 5000 LB PAYLOAD	1	≁													2	2	4														
24	M' B' TY PAYLOAD AND TOWED LOAD	1	≁													4	4	5														
25	FUNCTION' NG	3	≁	10,000 EA			1													1							1			1		
26	END' NCE	5	≁	10,000 EA			1													1							1			1		
27	ENG. COOL' NG W/6-BLADE FAN	1	**		94	105	1													3												
28	ENG. COOL' NG W/5-BLADE FAN	1	**		98	103	1													4												
29	VP LK SUBMERGED FUEL PUMP	1	**			125	1																									
	SUMMARY LOWEST (WORST) RATING						2	1	1			1	1	5	1	4	4	5		5	5						3			3		

(OVER)

TRUCK, CARGO, 2 1/2-TON, 6X6, M35 (XM35)

NOTES

1	H	INSUFFICIENT TIRE DEFLECTION AT [illegible] PSI TIRE PRESSURE. IMPENDING VALVE STEM FAILURES, EVIDENCE OF TIRE BEAD SLIPPAGE. RATING INVALIDATED BY LATER TESTS. (SEE LINE [illegible])
1	J	REQUIRES 10 PSI TIRE PRESSURE. RATING INVALIDATED BY LATER TESTS. (SEE LINE [illegible])
1	K, L	"TEST NOT CONDUCTED BECAUSE OF EXCESSIVE TIRE DEFLATION." RATING INVALIDATED BY LATER TESTS. (SEE LINE [illegible])
2	H	"OPERATED WITH GREATER DIFFICULTY THAN M[illegible] OR M135." RATING INVALIDATED BY LATER TESTS. (SEE LINE [illegible])
2	J	REQUIRES 11 PSI TIRE PRESSURE. RATING INVALIDATED BY LATER TESTS. (SEE LINE [illegible])
2	K	REQUIRES 10 PSI (FRONT) AND [illegible] PSI (REAR) TIRE PRESSURE. RATING INVALIDATED BY LATER TESTS. (SEE LINE [illegible])
2	L	"TEST NOT CONDUCTED BECAUSE OF EXCESSIVE TIRE DEFLATION." RATING INVALIDATED BY LATER TESTS. (SEE LINE [illegible])
3	H	PERFORMANCE INFERIOR TO M[illegible]. SEVERAL RUNS REQUIRED TO NEGOTIATE LONG GRADUAL SLOPES.
3	J	REQUIRES 14 PSI TIRE PRESSURE.
3	K	REQUIRES 11 PSI TIRE PRESSURE.
3	L	"TEST NOT CONDUCTED BECAUSE OF EXCESSIVE TIRE DEFLATION."
4	H	"TRAVEL IN SAND DUNES UNSATISFACTORY."
5	U, X	COOLING DIFFICULTIES EXPERIENCED.
5, 6	O, P	EXTRAPOLATION OF RATING ([illegible]-N).
7	N, O, P, X	DATA INCONCLUSIVE-INDICATES VARIOUS UNSATISFACTORY COOLING CONDITIONS. RATING INVALIDATED.
8	N, O, P, X	[illegible] DEGREES COOLANT DIFFERENTIAL INDEX; [illegible] DEGREES ENGINE OIL TEMPERATURE AT [illegible] DEGREES AMBIENT, ALTITUDE OF [illegible] FEET. RATING INVALIDATED BY LATER TESTS. (SEE LINE 18)
9	N, O, P	INCIPIENT VAPOR LOCK ENCOUNTERED UNDER SEVERE OPERATING CONDITIONS USING FUEL ADJUSTED TO [illegible] PSI RVP AT [illegible] DEGREES.
10	N	NO VAPOR LOCK TENDENCIES. PUMP UNRELIABLE.
11	A	EXCESSIVE FRONT TIRE WEAR. AVERAGE LIFE-LEFT FRONT [illegible] MILES; RIGHT FRONT [illegible] MILES.
11, 12	P	EXTRAPOLATION OF RATINGS 11, 12-O. RATIO OF 1:1 USED.
13	N	COOLANT AND ENGINE OIL TEMPERATURES EXCEED ALLOWABLE DIFFERENTIALS. MAX ENGINE OIL TEMPERATURES WAS [illegible] DEGREES IN [illegible] DEGREES AMBIENT. RATING INVALIDATED BY LATER TESTS. (SEE LINE [illegible]-27)
13	O, P	EXTRAPOLATION OF RATING 13-N. RATIO OF 1:1 USED. RATING INVALIDATED BY LATER TESTS. (SEE LINE [illegible]-27)
14	N	BAFFLES IMPROVED COOLING CHARACTERISTICS ONLY SLIGHTLY. RATINGS INVALIDATED BY LATER TESTS. (SEE LINES [illegible]-27)
14	O, P	EXTRAPOLATION OF RATING 14-N. RATIO OF 1:1 USED. RATINGS INVALIDATED BY LATER TESTS. (SEE LINE [illegible]-27)
15	N	IN H-[illegible] GEAR AT 1400 RPM THE MAX ENGINE OIL GALLERY AND COOLANT TEMPERATURES WERE [illegible] DEGREES AND [illegible] DEGREES, RESPECTIVELY, WHEN OPERATING IN AMBIENT OF [illegible]-100 DEGREES. THE MAX ENGINE OIL GALLERY TEMPERATURE REACHED [illegible] DEGREES IN H-[illegible] GEAR, [illegible] RPM IN [illegible]-[illegible] DEGREES AMBIENT. RATING INVALIDATED BY LATER TESTS. (SEE LINES [illegible]-27)
15	O, P	EXTRAPOLATION OF RATING 15-N. RATIO OF 1:1 USED. RATINGS INVALIDATED BY LATER TESTS. (SEE LINES [illegible]-27)
16	N	THE WINCH BUMPER CAUSED AN INCREASE OF COOLANT TEMPERATURE OF [illegible] DEGREES AT [illegible] RPM ENGINE SPEED TO [illegible] DEGREES AT 1400 RPM ENGINE SPEED. RATINGS INVALIDATED BY LATER TESTS. (SEE LINE [illegible]-27)
16	O, P	EXTRAPOLATION OF RATING 16-N. RATIO OF 1:1 USED. RATINGS INVALIDATED BY LATER TESTS. (SEE LINES [illegible]-27)
17	N, O, P	ENGINE OIL GALLERY TEMPERATURE [illegible] DEGREES, TRANSMISSION OIL [illegible] DEGREES IN AMBIENT TEMPERATURES OF 112-120 DEGREES.
18	N	ENGINE OIL TEMPERATURE WOULD BECOME CRITICAL AT HIGH RPM, LOW SPEED. MAX WAS [illegible] DEGREES AT [illegible] MPH, [illegible] DEGREES AMBIENT TEMPERATURE.
18	O, P	EXTRAPOLATION OF RATING 18-N. RATIO OF 1:1 USED.
19	N, O, P	REQUIRED [illegible] OCTANE MOTOR FUEL (KNOCK-IN, KNOCK-OUT METHOD) UNDER FULL LOAD, FULL THROTTLE CONDITIONS IN [illegible] DEGREES AMBIENT.
21	N, O, P	ENGINE STALLED AND CARBURETOR FLOODED ON FUEL ADJUSTED TO [illegible] PSI RVP AT [illegible] DEGREES.
22	J, K, L	RECOMMENDS 12, 6, AND 2 PSI TIRE PRESSURE, RESPECTIVELY.
23	J, K	RECOMMENDS 16, 10, AND [illegible] PSI TIRE PRESSURE, RESPECTIVELY.
24	L	COULD NOT NEGOTIATE.
22, 23, 24	J, K, L	A 4 PER CENT OVER-RUNNING CLUTCH HAD NO EFFECT. (TESTED WITH AND WITHOUT.)
25, 26	ALL	NO STATEMENTS IN REPORT, THEREFORE ASSUMED TO BE SATISFACTORY.
27	N	"THE SIX-BLADED FAN DID RESULT IN A COOLING IMPROVEMENT OVER THE FIVE-BLADED FAN. THE COOLANT DIFFERENTIAL EXCEEDED THE [illegible] DEGREES SPECIFICATION IN L-1 GEAR AT FULL TORQUE ENGINE SPEED (1400 RPM) AND THE ENGINE OIL TEMPERATURE IN THE GALLY WAS BORDERLINE AT MAXIMUM HORSEPOWER ENGINE SPEED ([illegible] RPM). TRANSMISSION OIL TEMPERATURE IS CRITICAL DURING OPERATION AT [illegible] RPM AND HIGHER. THE TRANSFER CASE LUBRICANT MAY BECOME CRITICAL AT [illegible] DEGREES AMBIENT." THE AVERAGE COOLANT DIFFERENTIAL WAS 109 DEGREES F IN L-1 GEAR AT 1400 RPM.
28	N	SAME AS RATING 27-N THE COOLANT DIFFERENTIAL EXCEEDED SPECIFICATIONS IN ALL TEST RUNS WITH THE ENGINE DEVELOPING MAXIMUM TORQUE.
29	N, O, P	SEVERE SURGING AND CARBURETOR FLOODING ATTRIBUTED TO THE LOCATION OF THE FUEL LINE CARBURETOR WITH RESPECT TO THE ENGINE EXHAUST MANIFOLD, TESTED WITH FUEL ADJUSTED TO [illegible] PSI AT [illegible] DEGREES. RATING INVALIDATED BECAUSE RELOCATION OF GASOLINE LINE ELIMINATED TROUBLE. (SEE LINE [illegible])
30	N	"THE ENGINE WOULD NOT PROPERLY COOL UNDER CONDITIONS OF HIGH AMBIENT TEMPERATURES MODIFICATIONS WERE MADE TO THE ENGINE AND COOLING SYSTEMS WHICH IMPROVED THE VEHICLES COOLING CHARACTERISTICS; HOWEVER THEY STILL DID NOT MEET ORDNANCE REQUIREMENTS.
30	O, P	EXTRAPOLATION TO TEMPERATURES.
31	N	"TWO ENGINE FAILURES WERE ENCOUNTERED IN THE M[illegible] TRUCK AND ONE ENGINE FAILURE OCCURRED DURING THE FULL-THROTTLE, FULL-LOAD COOLING TESTS USING A FIELD DYNAMOMETER, WHILE OPERATING AT MAXIMUM ENGINE SPEED."
30, 31	ALL	RATINGS INVALIDATED. ENGINES AND TRANSMISSIONS WERE EXPERIMENTAL R AND D ITEMS; HAVE NOT BEEN INCORPORATED INTO VEHICLES.

EQUIPMENT TESTED: CARRIER, PERSONNEL, FULL-TRACKED, M113 (T113E2)

REPT. REF.	REPORT NUMBER	LOCATION AND YEAR OF TEST	EQUIPMENT MODIFICATIONS INCORPORATED INTO TEST ITEM	SUPPORTING EQUIPMENT AND OR LOADS UTILIZED
•	TB5–1401/400 (U)	YUMA TEST STATION SUMMERS 1957, 1958	T113 VEHICLE W/ T116 TRACK	COMBAT LOADED
⊕	TB5–1401/474 (RATED FROM TB5–1401/450) (C)	YUMA TEST STATION SUMMER, 1958	T113E1 VEHICLE. TWO ENGINES USED DURING TEST: 186 HP UNIT, AND 200 HP UNIT.	21,000 LB AND 24,000 LB GVW
≁	TB5–1401/505/I (U)	YUMA TEST STATION SUMMER 1958	T113E1 VEHICLE. ENGINE MODIFIED TO INCREASE OUTPUT TO 200 HP	LOADED TO 24,000 GVW
••	TB5–1401/505/II (U)	YUMA TEST STATION SUMMER 1959	T113E1 VEHICLE. MODIFIED TO CLOSELY RESEMBLE THE M113	
⊕⊕	DPS/IT-5175/1 (U)	APG SUMMER, 1959	PREPRODUCTION M113 W/ TX200-2X TRANSMISSION	22,900 LB GVW

LINE ITEM NO.: 405225 | **STOCK NO.:** [illegible] | **TYPE CLASSIFICATION:** STD-A | **OTCM REFERENCE:** 36040–C; 37119–U; 36900–C; 37087–U; 36908–C;

SUMMARY OF PERFORMANCE:

Cooling of vehicle is generally satisfactory to 115° except that engine and differential oil might overheat slightly at the 115° temperature. Octane limits are 85-90 (research method). Mobility characteristics were excellent over all tested desert terrains. Dust and high temperature operation has affected the steering system. Endurance characteristics are generally satisfactory; however, minor suspension failures were noted, vibration was stated as being the cause. Vapor handling characteristics were evaluated on early T113 and T113E1 vehicles; these vehicles were satisfactory in this respect.

ENVIRONMENTAL FACTORS

A PAVED SURFACES; B PREP. GRAVEL SURFACES; C HARD UNPREP. SURFACES; D STONY OR ROCKY GROUND; E GRAVEL LOOSE; F ALLUVIAL FANS (SAND, SILT, GRAVEL AND ROCKS); G DESERT PAVEMENT (SAND, SILT AND GRAVEL); H DUNE SAND; I SAND PLAIN (LOOSE SAND); J PREP. SAND SLOPE—10%; K PREP. SAND SLOPE—15%; L PREP. SAND SLOPE—20%; M WATER; N TEMPERATURE (TEST AMBIENT); O TEMPERATURE (115 F — BELOW 3000 FT. ALT.); P TEMPERATURE (125 F — BELOW 3000 FT. ALT.); Q SOLAR RADIATION; R DUST (AIR BORNE); S BLOWING SAND; T RAINFALL; U HILLY OR MOUNTAINOUS; V MUD; W VEGETATION; X ALTITUDE; Y; Z

TEST

TEST NO.	TYPE	NO. OF ITEMS	REPT. REF.	EXTENT	AMB. TEMP. MIN.	AMB. TEMP. MAX.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	ENG COOL'NG	1	•		85	118																										
2	RD COOL'NG	1	•		50	118																										
3	OCT RT'NG	1	•		85	118																										
4	VP LK	1	•		85	118																										
5	M'B'TY	1	•		50	118																										
6	FUNCTION'G	1	•	3719 MILES	50	118																										
7	END'NCE	1	•	3719 MILES																												
8	CR CMFT	1	•		50	118																										
9	ENG COOL'NG	1	⊖																													
10	RD COOL'NG	1	⊕																													
11	VP LK	1	⊖																													
12	FUNCTION'G	1	⊖																													
13	M'B'TY	1	⊖																													
14	ENG COOL'NG	1	≁		67	81																										
15	VP LK	1	≁	2 RUNS	100	102																										
16	M'B'TY	1	≁																													
17	ENG COOL'NG	1	••		95	109														1	1	3										
18	RD COOL'NG	1	•••		93	93														1	3	3										
19	CROSS COUNTRY COOL'NG	1	••		81	95														1	1	1										
20	OCT RT'NG	1	••																	1												
21	M'B'TY	1	••				1	1	1		1	1	1		1	1	1	1														
22	FUNCTION'G	1	••	1446 MI			1	1	1		1	1	1		3	1	1	1		3	3	3		3				1		1		
23	END'NCE	1	••	1446 MI			1	1	1		1	1	1		1	1	1	1		1								1		1		
24	END'NCE	1	⊕⊕	[illegible] MI			1	1	1	1	1																					
	SUMMARY LATEST CURRENT RATING						1	1	1	1	1	1	1		3	1	1	1		3	3	3		3				1		1		

NOTES

(OVER)

CARRIER, PERSONNEL, FULL-TRACKED M113 (T113E2)

1	O, P	ENGINE OIL SLIGHTLY EXCEEDED 230 DEGREES F REQUIREMENT WHEN EXTRAPOLATED TO 115 DEGREES F AND 125 DEGREES F.
3	N, O	"THE MAXIMUM OCTANE NUMBER WAS 94.3 AT AN ENGINE SPEED OF 3000 RPM."
4	N, O, P	TESTED WITH FUEL ADJUSTED TO 6 PSI AT 125 DEGREES F. "THE VEHICLE WAS UNABLE TO DELIVER SUFFICIENT FUEL TO PERMIT SATISFACTORY OPERATION AFTER SOAK PERIOD."
5	H	"OPERATION IN CALIFORNIA SAND DUNES WAS UNSUCCESSFUL AS THE TEST VEHICLES WERE FREQUENTLY IMMOBILIZED."
5	ALL	"THE MOBILITY OF THE CARRIER COULD BE IMPROVED BY ADDING A WIDER TRACK."
6	M	AVERAGE WATER SPEED IS 3.86 MPH.
6	R	DUST LOADING OF THE AIR CLEANER DURING DUST COURSE OPERATION DID NOT AFFECT ENGINE PERFORMANCE.
7	ALL	"COMPONENT IMPROVEMENT REQUIRED FOR SUSPENSION, HULL, AUD ENGINE."
8	ALL	"JOLTING RIDE OFF-ROAD, HIGH TEMPERATURES, NOISE LEVEL, CRAMPED SEATING SPACE."
1 THRU 8	ALL	ALL RATINGS INVALIDATED; TEST ITEM WAS A T113.
9, 10	N	"PRELIMINARY COOLING TESTS INDICATED SATISFACTORY ENGINE COOLING."
11	N	"VAPOR LOCK TESTS REVEALED NO FUEL HANDLING PROBLEMS."
12	N	"VEHICLE DID NOT MEET 4 MPH WATER OPERATION REQUIREMENT." (THIS REQUIREMENT WAS LATER RECINDED.)
13	ALL	"MOBILITY CHARACTERISTICS ARE SUPERIOR TO M59"
9 THRU 13	ALL	RATINGS INVALIDATED. TEST VEHICLE WAS A T113E1.
15	N, O	FUEL ADJUSTED TO 7.5 PSI AT 115 DEGREES F.
16	A	UNABLE TO ATTAIN 40 MPH SPEED.
16	ALL	UNABLE TO CLIMB A 24-INCH WALL IN REVERSE. (REQUIREMENT NOT KNOWN).
14, 15, 16	ALL	RATINGS INVALIDATED. REPORT STATES "TEST DATA...DOES NOT FULLY REPRESENT THE ANTICIPATED ENVIRONMENTAL PERFORMANCE OF THE M113 CARRIER."
17	P	WHEN EXTRAPOLATED TO 125 DEGREES F, TRANSMISSION OIL TEMPERATURE WOULD SLIGHTLY EXCEED ALLOWABLE (5 DEGREES F).
18	O, P	"ALTHOUGH ALL COMPONENTS COOLED SATISFACTORILY IN AN AMBIENT TEMPERATURE OF 90 DEGREES F, EXTRAPOLATION TO 115 DEGREES F INDICATES POSSIBLE OVERHEATING OF ENGINE AND DIFFERENTIAL OILS. RATING QUESTIONED; FULL LOAD COOLING TESTS DID NOT INDICATE THIS PROBLEM.
20	O	MAXIMUM OCTANE REQUIREMENT WAS 90 (RESEARCH) AT 2800 -3100 RPM. THE MINIMUM REQUIREMENT WAS 85 (RESEARCH) AT 2400 RPM.
22	I, R	A NOTICEABLE BINDING OF THE LEFT STEER LATERAL AND THE HORIZONTAL AND VERTICAL SEAT MOVEMENT WAS OBSERVED AT THE COMPLETION OF DUST OPERATION.
22	N	THE PIVOT STEER BRAKES BECAME SELF-APPLIED SEVERAL TIMES DURING FULL LOAD TESTING. TEMPERATURE INCREASE WAS GIVEN AS THE CAUSE.
22	O, P	EXTRAPOLATION OF RATING 9-N.
23	A	VIBRATION FAILURES ON PAVED SURFACES. INCLUDED WERE: RIGHT FRONT TRACK SHROUD-TO-HULL WELD, LEFT FRONT BUMPER STOP, ENGINE GROUND STOP.

APPENDIX E

STATION TEMPERATURE CALCULATIONS

SUMMARY OF CALCULATIONS
DETERMINATION OF METHOD OF ESTIMATING TEMPERATURE FREQUENCY CURVES
SELECTED STATIONS

Station	El Paso, U.S.A.			Fresno, U.S.A.			Phoenix, U.S.A.			Yuma, U.S.A.		
Latitude	31° 48' N			36° 42' N			33° 26' N			32° 40' N		
Longitude	106° 24' W			119° 43' W			112° 01' W			114° 36' W		
No. of Years	8			8			8			8		
Elevation	3916'			327'			1107'			206'		
		Calculated Frequency (Summation)			Calculated Frequency (Summation)			Calculated Frequency (Summation)			Calculated Frequency (Summation)	
Temperature Intervals (°F)	Actual Frequency Summation	Normal Distribution	$\beta - \frac{1}{2\pi} \sin \beta\ 360$	Actual Frequency Summation	Normal Distribution	$\beta - \frac{1}{2\pi} \sin \beta\ 360$	Actual Frequency Summation	Normal Distribution	$\beta - \frac{1}{2\pi} \sin \beta\ 360$	Actual Frequency Summation	Normal Distribution	$\beta - \frac{1}{2\pi} \sin \beta\ 360$
45/50						.0						
50/55				.3	2.3	.7						
55/60			.1	2.5	5.4	3.5						
60/65	.4	4.6	2.0	9.7	11.0	9.1						
65/70	5.4	11.7	9.1	21.5	20.0	18.0	.2	2.9	1.0	.1	1.5	2.0
70/75	21.9	24.7	22.8	35.1	32.5	30.1	3.0	7.9	6.0	.9	4.5	7.8
75/80	42.9	42.8	41.8	47.8	47.2	44.2	13.8	16.8	16.1	5.4	11.1	16.9
80/85	61.5	62.6	62.2	60.5	62.4	58.8	31.9	31.0	31.5	19.9	23.0	30.5
85/90	77.3	79.4	80.5	73.3	75.9	72.6	49.2	48.9	50.0	41.3	39.7	46.7
90/95	91.3	90.9	92.9	84.8	86.2	84.0	64.2	67.0	68.8	57.7	58.6	63.3
95/100	98.9	96.7	98.8	95.5	93.0	92.3	79.8	81.8	84.2	72.8	75.8	77.8
100/105	100.1	99.0	99.9	99.3	96.9	97.3	92.5	91.5	94.3	87.9	88.2	89.0
105/110	100.2	99.8	100.0	100.0	98.8	99.7	99.0	96.7	99.0	97.5	95.0	96.2
110/115				100.1	99.6	100.0	100.0	98.9	99.9	99.8	98.4	99.4
115/120										99.9	99.6	99.9
T_o			58*			48*			64*			61*
T_m	82		82	82		82	90		90	91.3		91.0
T_{mdm}	94		94	99		99	103		103	106		106
T_{max}	106		106**	115		116**	118		116**	123		121**

Station	Bengasi, Libya			Tripoli, Libya			Badahoz, Spain			Ashkharad, USSR		
Latitude	32° 06' N			32° 54' N			38° 53' N			37° 58' N		
Longitude	20° 20' E			13° 17' E			06° 49' W			58° 20' E		
No. of Years	2			8			4			6		
Elevation	UNK			14'			607'			755'		
		Calculated Frequency (Summation)			Calculated Frequency (Summation)			Calculated Frequency (Summation)			Calculated Frequency (Summation)	
Temperature Intervals (°F)	Actual Frequency Summation	Normal Distribution	$\beta - \frac{1}{2\pi} \sin \beta\ 360$	Actual Frequency Summation	Normal Distribution	$\beta - \frac{1}{2\pi} \sin \beta\ 360$	Actual Frequency Summation	Normal Distribution	$\beta - \frac{1}{2\pi} \sin \beta\ 360$	Actual Frequency Summation	Normal Distribution	$\beta - \frac{1}{2\pi} \sin \beta\ 360$
45/50												
50/55							.3	.4	.1			
55/60							4.8	1.3	.7	.2	.0	.4
60/65	.3	.2	.0	.6	1.4	.0	15.0	3.9	3.8	.8	.2	3.0
65/70	5.8	3.4	3.5	6.7	7.8	.4	21.0	9.6	10.3	3.2	.8	9.1
70/75	22.3	20.6	23.3	24.8	25.8	13.9	30.2	19.8	22.0	10.5	3.3	19.6
75/80	56.2	57.1	57.2	54.6	54.9	50.0	39.5	34.8	37.4	21.7	10.0	33.9
80/85	88.5	88.1	86.8	83.5	81.5	85.7	51.9	52.5	53.0	37.5	23.5	50.0
85/90	98.9	98.5	99.1	94.8	95.2	99.6	62.1	69.9	69.6	46.7	43.4	66.8
90/95	99.7	99.9	100.0	98.2	99.3	100.0	81.8	83.6	82.8	60.1	65.2	80.4
95/100	100.0	100.0	100.0	99.2	99.9	100.0	93.2	92.4	91.8	78.6	82.8	90.9
100/105				99.6	100.0	100.0	99.5	97.1	98.0	97.1	93.4	97.2
105/110				99.8	100.0	100.0	99.9	99.0	99.8	100.0	98.0	99.5
110/115				99.9	100.0	100.0						
115/120												
T_o			65*			68*			54*			55*
T_m	79+		79	80		80	84+		84+	85		85
T_{mdm}	86+		86+	86		86	99		99+	100		100
T_{max}	100+		93**	114		92**			114**	113		115**

\+ estimated

* calculated $T_o = 3\,T_m - 2\,T_{mdm}$

** calculated $T_{max} = 2\,T_{mdm} - T_m$

$$\beta = \frac{T - T_o}{T_{max} - T_o}$$

COSINE DISTRIBUTION OF TEMPERATURES

South Asia Desert Region
(Iran, Pakistan, Afghanistan, India)
Month of July

Country-Town	Location Coordinates Lat.	Long.	Mean Temperature (°F)	Mean Daily Maximum Temperature (°F)	Absolute Maximum Temperature (°F)	Absolute Minimum Temperature (°F)	Percent of Time Temperature at or Below 82°F	100°F	103°F	113°F	117°F	125°F
Iran	37	55	75	91	107	43	71.0	99.1	99.9	100.0	100.0	100.0
	37	56	77	93	109	45	65.4	98.3	99.5	100.0	100.0	100.0
	37	57	77	95	113	41	63.6	96.0	98.4	100.0	100.0	100.0
	37	58	70	89	108	32	79.0	99.2	99.9	100.0	100.0	100.0
	37	59	70	89	108	32	79.0	99.2	99.9	100.0	100.0	100.0
	37	60	79	92	105	53	61.8	99.4	99.9	100.0	100.0	100.0
	36	48	76	95	114	38	65.7	96.3	98.2	99.9	100.0	100.0
	36	49	72	95	118	26	71.0	90.7	97.5	99.9	99.9	100.0
	36	50	80	95	110	50	56.8	97.2	99.0	100.0	100.0	100.0
	36	51	75	95	115	35	67.4	96.0	98.1	99.9	100.0	100.0
	36	52	75	90	105	45	72.5	99.7	99.0	100.0	100.0	100.0
	36	53	75	89	103	47	73.8	99.9	100.0	100.0	100.0	100.0
	36	54	75	89	103	47	73.8	99.9	100.0	100.0	100.0	100.0
	36	55	77	94	111	43	64.5	97.5	99.0	100.0	100.0	100.0
	36	56	82	96	110	54	50.0	96.5	98.9	100.0	100.0	100.0
	36	57	86	96	106	66	30.6	98.0	99.8	100.0	100.0	100.0
	36	58	78	93	108	48	63.5	98.7	99.7	100.0	100.0	100.0
	36	59	71	90	109	33	77.0	99.0	99.9	100.0	100.0	100.0
	36	60	78	92	106	50	64.4	99.1	99.9	100.0	100.0	100.0
	36	61	85	93	101	69	31.8	99.9	100.0	100.0	100.0	100.0
	35	48	70	90	110	30	77.7	98.8	99.7	100.0	100.0	100.0
	35	49	75	95	115	35	67.4	96.1	98.1	99.9	100.0	100.0
	35	50	83	97	111	55	46.4	95.3	98.3	100.0	100.0	100.0
	35	51	89	103	117	61	26.0	95.0	90.8	99.8	100.0	100.0
	35	52	92	102	112	72	9.1	84.7	93.2	100.0	100.0	100.0
	35	53	95	101	107	83	0	85.8	97.3	100.0	100.0	100.0
	35	54	95	101	107	83	0	85.8	97.3	100.0	100.0	100.0
	35	55	95	101	107	83	0	85.8	97.3	100.0	100.0	100.0
	35	56	96	100	104	88	0	90.9	97.3	100.0	100.0	100.0
	35	57	92	95	98	86	0	100.0	100.0	100.0	100.0	100.0

COSINE DISTRIBUTION OF TEMPERATURES (Cont'd)

South Asia Desert Region
(Iran, Pakistan, Afghanistan, India)
Month of July

Country-Town	Location Coordinates Lat.	Long.	Mean Temperature (°F)	Mean Daily Maximum Temperature (°F)	Absolute Maximum Temperature (°F)	Absolute Minimum Temperature (°F)	Percent of Time Temperature at or Below 82°F	100°F	103°F	113°F	117°F	125°F
Iran (Cont'd)	35	58	89	93	97	81	0.1	100.0	100.0	100.0	100.0	100.0
	35	59	86	94	102	70	26.0	99.9	100.0	100.0	100.0	100.0
	35	60	77	92	107	47	66.2	99.0	99.9	100.0	100.0	100.0
	35	61	87	94	101	73	9.1	99.9	100.0	100.0	100.0	100.0
	34	49	73	95	117	29	70.0	95.8	97.8	99.9	100.0	100.0
	34	50	70	92	114	26	75.7	97.7	98.9	99.9	100.0	100.0
	34	51	80	100	120	40	55.0	90.9	94.3	99.6	99.9	100.0
	34	52	91	100	109	73	9.1	90.9	97.3	100.0	100.0	100.0
	34	53	93	102	111	75	4.5	84.0	93.5	100.0	100.0	100.0
	34	54	94	105	116	72	7.1	75.8	85.3	99.8	100.0	100.0
	34	55	96	107	118	74	3.7	67.9	79.0	99.0	99.9	100.0
	34	56	96	106	116	76	2.0	69.5	81.5	99.7	100.0	100.0
	34	57	93	102	111	75	4.5	83.9	93.5	100.0	100.0	100.0
	34	58	87	98	109	65	28.0	94.8	98.6	100.0	100.0	100.0
	34	59	82	95	108	56	50.0	97.9	99.5	100.0	100.0	100.0
	34	60	85	96	107	63	36.8	96.5	99.6	100.0	100.0	100.0
	33	49	80	103	126	34	54.3	87.0	90.9	98.3	99.3	99.9
	33	50	70	85	100	40	84.8	100.0	100.0	100.0	100.0	100.0
	33	51	73	93	113	33	71.8	97.4	98.9	100.0	100.0	100.0
	33	52	80	100	120	40	55.0	90.9	94.2	99.6	99.9	100.0
	33	53	88	95	102	74	13.0	99.8	100.0	100.0	100.0	100.0
	33	54	92	103	114	70	11.9	82.5	90.9	99.9	100.0	100.0
	33	55	94	105	116	72	7.2	75.8	85.5	99.9	100.0	100.0
	33	56	95	108	121	69	9.1	69.0	78.5	97.8	99.8	100.0
	33	57	96	108	120	72	5.7	66.4	77.1	98.1	99.9	100.0
	33	58	90	103	116	64	21.5	83.9	90.8	99.8	100.0	100.0
	33	59	84	97	110	58	42.7	95.8	98.7	100.0	100.0	100.0
	33	60	81	94	107	55	53.8	98.5	99.9	100.0	100.0	100.0
	32	50	86	100	114	58	36.4	90.9	95.4	99.9	100.0	100.0
	32	51	70	90	110	30	77.7	98.8	99.7	100.0	100.0	100.0

COSINE DISTRIBUTION OF TEMPERATURES (Cont'd)

South Asia Desert Region
(Iran, Pakistan, Afghanistan, India)
Month of July

Country-Town	Location Coordinates Lat.	Long.	Mean Temperature (°F)	Mean Daily Maximum Temperature (°F)	Absolute Maximum Temperature (°F)	Absolute Minimum Temperature (°F)	Percent of Time Temperature at or Below 82°F	100°F	103°F	113°F	117°F	125°F
Iran (Cont'd)	32	52	77	95	113	41	64.0	96.4	98.5	100.0	100.0	100.0
	32	53	80	100	120	40	55.0	90.9	94.1	99.6	99.9	100.0
	32	54	86	97	108	64	32.0	96.2	99.1	100.0	100.0	100.0
	32	55	92	102	112	72	9.1	84.9	93.2	100.0	100.0	100.0
	32	56	92	104	116	68	13.7	80.0	88.5	99.9	100.0	100.0
	32	57	94	110	126	62	16.4	68.2	76.3	95.0	98.3	99.9
	32	58	95	110	125	65	12.7	66.4	75.0	95.2	98.5	100.0
	32	59	90	104	118	62	23.0	81.8	88.7	99.5	99.9	100.0
	32	60	83	95	107	59	45.9	98.2	99.8	100.0	100.0	100.0
	32	61	88	97	106	70	19.2	97.2	99.8	100.0	100.0	100.0
	31	51	83	100	117	49	47.1	90.9	94.9	99.9	100.0	100.0
	31	52	72	90	108	36	76.0	99.1	99.9	100.0	100.0	100.0
	31	53	70	90	110	30	77.7	98.8	99.7	100.0	100.0	100.0
	31	54	80	100	120	40	55.0	90.9	94.2	99.6	99.9	100.0
	31	55	86	100	114	58	36.0	90.9	95.3	99.9	100.0	100.0
	31	56	88	102	116	60	29.3	86.8	92.7	99.9	100.0	100.0
	31	57	90	99	108	72	12.2	93.5	98.4	100.0	100.0	100.0
	31	58	104	115	126	82	0	32.3	47.3	85.3	94.9	99.9
	31	59	98	112	126	70	6.0	57.0	67.7	92.7	97.5	99.9
	31	60	92	100	108	76	3.9	90.9	87.8	100.0	100.0	100.0
	31	61	87	99	111	63	29.8	92.9	97.2	100.0	100.0	100.0
	30	51	96	110	124	68	9.1	64.2	73.8	95.5	98.8	100.0
	30	53	79	96	113	45	58.8	95.8	98.2	100.0	100.0	100.0
	30	54	75	95	115	35	67.2	96.0	98.1	99.9	100.0	100.0
	30	55	84	100	116	52	43.8	90.9	95.0	99.9	100.0	100.0
	30	56	89	100	111	67	20.6	90.9	96.3	100.0	100.0	100.0
	30	57	89	100	111	67	20.6	90.9	96.3	100.0	100.0	100.0
	30	58	100	107	114	86	0	50.0	70.9	99.9	100.0	100.0
	30	59	103	115	127	79	0.2	38.3	50.0	86.0	94.6	99.9
	30	60	95	101	107	83	0	85.8	97.2	100.0	100.0	100.0

COSINE DISTRIBUTION OF TEMPERATURES (Cont'd)

South Asia Desert Region
(Iran, Pakistan, Afghanistan, India)
Month of July

Country-Town	Location Coordinates Lat.	Long.	Mean Temperature (°F)	Mean Daily Maximum Temperature (°F)	Absolute Maximum Temperature (°F)	Absolute Minimum Temperature (°F)	Percent of Time Temperature at or Below 82°F	100°F	103°F	113°F	117°F	125°F
Iran (Cont'd)	30	61	85	99	113	57	39.9	92.6	97.0	100.0	100.0	100.0
	29	52	95	102	109	81	0.1	82.1	94.1	100.0	100.0	100.0
	29	55	87	98	109	65	28.0	93.6	98.6	100.0	100.0	100.0
	29	56	85	100	115	55	40.5	90.9	95.1	99.9	100.0	100.0
	29	57	86	100	114	58	36.6	90.9	95.5	99.9	100.0	100.0
	29	58	93	104	115	71	9.1	79.2	88.3	99.9	100.0	100.0
	29	59	103	110	117	89	39.4	0	50.0	98.2	100.0	100.0
	29	60	95	103	111	79	0.6	78.7	90.9	100.0	100.0	100.0
	29	61	85	95	105	65	35.5	98.8	99.9	100.0	100.0	100.0
	28	52	95	106	117	73	5.1	72.0	82.3	99.5	100.0	100.0
	28	53	95	110	115	65	20.3	84.8	91.9	99.9	100.0	100.0
	28	54	95	107	119	71	7.2	70.2	80.1	98.8	99.9	100.0
	28	56	95	106	117	73	5.1	71.7	82.3	99.5	100.0	100.0
	28	57	95	108	121	69	9.1	68.8	78.4	97.8	99.8	100.0
	28	58	100	111	122	78	0.5	50.0	63.8	99.1	99.0	100.0
	28	59	101	111	121	81	0.1	45.0	60.0	95.2	99.2	100.0
	28	60	98	108	118	78	0.8	60.0	73.7	98.8	99.9	100.0
	28	61	90	102	114	66	9.1	85.8	92.9	99.9	100.0	100.0
	28	62	83	100	117	49	47.3	90.0	95.0	99.9	100.0	100.0
	27	54	95	110	125	65	12.7	66.3	75.2	95.2	98.6	100.0
	27	55	95	110	125	65	12.7	66.3	75.2	95.2	98.6	100.0
	27	58	99	110	121	77	1.0	55.0	68.0	96.2	99.6	100.0
	27	59	100	111	122	78	0.5	50.0	63.9	95.0	99.9	100.0
	27	60	100	111	122	78	0.5	50.0	63.9	95.0	99.9	100.0
	27	61	97	108	119	75	2.5	63.6	75.8	98.5	99.9	100.0
	27	62	93	104	115	71	9.1	79.2	88.1	99.9	100.0	100.0
	27	63	92	105	118	66	15.8	78.2	86.2	99.4	99.9	100.0

COSINE DISTRIBUTION OF TEMPERATURES (Cont'd)

South Asia Desert Region
(Iran, Pakistan, Afghanistan, India)
Month of July

Country-Town	Location Coordinates Lat.	Long.	Mean Temperature (°F)	Mean Daily Maximum Temperature (°F)	Absolute Maximum Temperature (°F)	Absolute Minimum Temperature (°F)	Percent of Time Temperature at or Below 82°F	100°F	103°F	113°F	117°F	125°F
Iran (Cont'd)	26	58	94	104	114	74	5.0	77.5	88.0	99.9	100.0	100.0
	26	59	93	107	121	65	15.2	73.7	82.0	98.2	99.8	100.0
	26	60	95	110	125	65	12.7	66.5	75.0	95.3	98.6	100.0
	26	61	95	110	125	65	12.7	66.5	75.0	95.3	98.6	100.0
	26	62	95	110	125	65	12.7	66.5	75.0	95.3	98.6	100.0
	26	63	95	110	125	65	12.7	66.5	75.0	95.3	98.6	100.0
Borujerd			74	90	106	42	73.7	99.7	99.9	100.0	100.0	100.0
Arak			80	95	110	50	55.7	97.1	99.0	100.0	100.0	100.0
Saveh			84	97	110	58	42.6	95.8	98.6	100.0	100.0	100.0
Qom			88	105	122	54	32.8	82.0	87.4	98.7	99.8	100.0
Karaj			77	90	103	51	69.0	99.9	100.0	100.0	100.0	100.0
Tehran			85	99	113	57	39.9	92.5	96.6	100.0	100.0	100.0
Isfahan			82	98	114	50	50.0	93.8	97.0	99.9	100.0	100.0
Yazd			91	100	109	73	9.1	90.9	97.2	100.0	100.0	100.0
Shahrud			79	90	101	57	63.7	99.9	100.0	100.0	100.0	100.0
Rafsenjan			88	103	118	58	30.5	85.2	90.9	99.7	99.9	100.0
Sabzawar			84	101	118	50	44.2	89.4	93.5	99.8	99.9	100.0
Kerman			84	101	118	50	44.2	89.4	93.5	99.8	99.9	100.0
Fakimum			73	90	107	39	75.0	99.3	99.9	100.0	100.0	100.0
Zahedan			87	98	109	65	28.0	95.5	98.6	100.0	100.0	100.0
Iranshahr			98	112	126	70	6.0	57.2	67.6	92.6	97.6	99.9
Zabol			91	103	115	67	16.6	83.5	90.9	99.9	100.0	100.0
Khash			85	101	117	53	41.0	89.4	93.9	99.9	100.0	100.0
Pakistan												
Nokkundi			97	110	123	71	5.8	61.4	72.1	95.8	99.0	100.0
Dalbandin			93	109	125	61	18.8	71.1	78.9	96.1	98.8	100.0
Ponjour			90	104	118	62	23.1	82.2	88.8	99.6	99.9	100.0
Badin			91	101	111	71	12.0	88.2	95.2	100.0	100.0	100.0
Hyderabad			93	104	115	71	9.1	79.3	88.2	99.9	100.0	100.0

COSINE DISTRIBUTION OF TEMPERATURES (Cont'd)

South Asia Desert Region
(Iran, Pakistan, Afghanistan, India)
Month of July

Country-Town	Location Coordinates Lat.	Location Coordinates Long.	Mean Temperature (°F)	Mean Daily Maximum Temperature (°F)	Absolute Maximum Temperature (°F)	Absolute Minimum Temperature (°F)	Percent of Time Temperature at or Below 82°F	100°F	103°F	113°F	117°F	125°F
Pakistan (Cont'd)												
Chhor			92	108	124	60	21.0	73.8	81.3	97.0	99.1	100.0
Las Bela			93	106	119	67	13.6	75.4	83.9	99.0	99.9	100.0
Kalat			74	93	112	36	70.7	97.6	99.0	100.0	100.0	100.0
Jacobabad			99	114	129	69	6.2	53.4	63.3	88.8	95.2	99.8
Sukkur			96	109	122	70	7.4	65.1	75.3	96.9	99.4	100.0
Sibi			100	113	126	74	2.2	50.0	61.4	90.9	97.8	99.9
Quetta			79	94	109	49	60.0	97.4	99.3	100.0	100.0	100.0
Chaman			88	101	114	62	27.8	89.0	94.4	99.9	100.0	100.0
Khanpur			97	110	123	71	5.8	61.4	72.1	95.7	99.0	100.0
Bahawalpur			96	108	120	72	5.5	66.3	77.1	98.1	99.8	100.0
Multan			95	106	117	73	6.0	76.8	86.8	99.9	100.0	100.0
Ft. Sandeman			87	100	113	61	31.3	90.9	95.9	100.0	100.0	100.0
Miranshah			88	99	110	66	24.2	93.1	97.7	100.0	100.0	100.0
Bannu			93	106	119	67	13.3	75.3	84.0	99.0	99.9	100.0
Khushab			95	107	119	71	7.3	70.1	80.4	98.7	99.9	100.0
Lyallpur			94	106	118	70	9.1	73.8	83.4	99.2	99.9	100.0
Montgomery			96	109	122	70	7.4	65.2	75.3	96.8	99.4	100.0
Dera Ismail Khan			95	108	121	69	9.1	68.7	78.4	95.7	99.7	100.0
Afghanistan												
Herat			87	97	107	67	26.0	96.7	99.3	100.0	100.0	100.0
Kandahar			89	105	121	57	28.7	81.4	87.2	98.7	99.8	100.0
India												
Sri Ganganagor			94	108	122	66	12.9	70.7	79.2	97.5	99.5	100.0
Bikaner			96	109	122	70	7.4	65.1	75.3	96.8	99.4	100.0
Phalodi			94	106	118	70	9.1	73.8	83.2	99.2	99.9	100.0
Jodhpur			93	106	119	67	13.3	75.4	83.8	99.0	99.9	100.0
Barmer			93	106	119	67	13.3	75.4	83.8	99.0	99.9	100.0
Bhuj			89	101	113	65	22.9	88.8	94.6	100.0	100.0	100.0

NORMAL DISTRIBUTION OF TEMPERATURES

South Asia Desert Region
(Coastal Stations)
Month of July

Location	Location Coordinates Lat.	Long.	Mean Temperature (T_m) (°F)	Absolute Maximum Temperature (T_{max}) (°F)	Temperature Range ($T_{max} - T_m$) (°F)	Est. Standard Deviation $\frac{T_{max} - T_m}{3}$ (°F)	Percent of Time Temperature at or Below 82°F	100°F	103°F	113°F	117°F	125°F
Iran	29	51	95	112	17	5.67	1.1	79.7	92.1	99.9	100.0	100.0
	27	56	94	107	13	4.33	0.3	91.7	98.1	100.0	100.0	100.0
	27	57	94	108	14	4.67	0.5	90.1	97.6	100.0	100.0	100.0
Bushire			91	115	24	8.00	13.0	87.0	93.3	99.7	99.9	100.0
Lingeh			91	109	18	6.00	6.7	93.3	97.7	99.9	100.0	100.0
Henjam			92	107	15	5.00	2.3	94.5	98.6	100.0	100.0	100.0
Jask			91	113	22	7.33	11.1	89.0	94.9	99.9	100.0	100.0
Chahbar			87	112	25	8.33	27.4	94.1	97.3	99.9	100.0	100.0
Pakistan												
Gwadar			87	112	25	8.33	27.4	94.1	97.3	99.9	100.0	100.0
Pasni			86	115	29	9.67	34.0	92.6	96.1	99.7	99.9	100.0
Ormara			87	117	30	10.00	30.9	90.3	94.3	99.5	99.9	100.0
Monora			86	109	23	7.67	30.1	96.6	98.7	100.0	100.0	100.0
Karachi			88	118	30	10.00	27.5	88.5	93.3	99.4	99.8	100.0
India												
Navanagar			90	106	16	5.33	6.7	97.0	99.3	100.0	100.0	100.0
Dwarka			84	108	24	8.00	40.1	97.7	99.1	99.9	100.0	100.0

APPENDIX F

DISPOSITION FORM, EXPLANATION AND AUTHORIZATION FOR THE PROJECT, OFFICE OF THE CHIEF, RESEARCH & DEVELOPMENT, DEPARTMENT OF THE ARMY

SUBJECT: Compilation of Map Overlays Showing Performance of Selected ORD Equipment Items Previously Listed at Environmental Test Test Stations

TO: Chief of Ordnance FROM: C/R&D DATE: 6 April 61 COMMENT No. 1

1. Since 1950 the Ordnance Corps has continuously recorded the results of its environmental test program using the ENVANAL techniques proposed by the Army Committee on Environment (ACE). It is anticipated that an Army-wide system for predicting equipment and materiel performance in the several military-geographic world regions will be adopted. The present testing procedures have never provided a means of making a cross-correlation of the results of equipment performance undergoing environmental test with environmental data collected, evaluated and synthesized by ACSI on a world-wide basis In order to obviate this shortcoming OCRD, with ACSI's concurrence, assigned the Chief of Engineers and the Quartermaster Corps several projects which are designed to develop a "bridging system" which could be used in relating the results of the Technical Services end item environmental test to actual world-wide military-geographic regions delineated by ACSI.

2 Under the above assignment of responsibilities, the Corps of Engineers was directed to assume responsibility for preparation of terrain analogs, showing the physiography, soil, drainage, and vegetation conditions as they exist at Yuma and comparing these individual environmental factors, as well as the complex of environmental characteristics, as they would be found in the other hot arid regions of the world. The Quartermaster Corps was assigned responsibility for the production of analog studies of the Yuma climatic conditions with these climatic conditions found in other hot arid regions of the world Similar studies are being prepared by the Corps of Engineers and the Quartermaster Corps for Ft Sherman (humid tropics), Fort Greely (cold-wet), Fort Churchill (Arctic), and Tuto-Camp Century (Polar)

3 It is assumed that if an end item gave satisfactory performance during all seasons of the year, in any or all environmental complexes found at one or more of the test sites listed in paragraph 2 above, satisfactory performance in comparable world military geographic regions could be predicted with assurance

4 Since Ordnance Corps has been the leader in the utilization of the ENVANAL techniques for evaluating environmental test results, it is requested that you provide this office with a series of map overlays of Yuma and other environmental test stations for which data are available to show the performance rating of a few selected, environmentally sensitive Ordnance items essential to combat which have reasonably complete

test histories. The format envisioned would be simply a tracing paper overlay covering the test station area represented by the testing condition rated in the test history. The portion of the station map representing an appreciable change in environmental conditions, but in which no tests were actually made, will be left blank indicating uncertainty. The zone or sub-zones which are applicable will be assigned an appropriate number or symbol to indicate the rated performance of the item.

BY DIRECTION OF THE CHIEF OF RESEARCH AND DEVELOPMENT:

s/

WILLIAM W. BEVERLEY
Colonel, GS
Asst Dir of Army Research

AD ______________ Accession No. ______________

Southwest Research Institute, San Antonio, Texas.

A STUDY OF THE FEASIBILITY OF DEVELOPING OVERLAY MAPS TO INDICATE PERFORMANCE CAPABILITIES OF ORDNANCE EQUIPMENT IN SELECTED WORLD ENVIRONMENTS. Carroll G. Robinson and Howard M. Bunch.

June 1962. 114 pp. including illustrations, tables and appendixes. (Contract No. DA-23-072-ORD-1375. OCO R&D Project No. TB5-1401. DA Project No. 598-09-004.) Unclassified report.

This document was an evaluation of a specific methodology for attempting to predict performance of Ordnance self-propelled vehicles in selected world environments using presently available vehicle test data and world geographical data as inputs. Vehicles selected for evaluation were: tank, 90mm gun, full-tracked, M48; carrier, personnel, armored, full-tracked, M113; truck, cargo, 2-1/2-ton, M35; and carrier, light weapons, infantry, 4 × 4, M274. The South Asian desert was the geographical area used in the evaluation.

General performance limits of a vehicle can be plotted for a given area. However, the degree of reliability of these plots is severely limited by the lack of definitive data relating vehicle performance to precise soil and terrain definitions. Suggestions were given for improving the system.

UNCLASSIFIED

1. Deserts--trafficability
2. Military equipment--climatic factors
3. Vehicles--performance
4. Vehicles--temperature factors
5. Vehicles--test methods

I. Contract No. DA-23-072-ORD-1375

II. Robinson, C. G., and Bunch, H. M.

III. A Study of the Feasibility of Developing Overlay Maps to Indicate Performance Capabilities of Ordnance Equipment in Selected World Environments

DISTRIBUTION: Copies obtainable from ASTIA-DSC

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AD ______________ Accession No. ______________

Southwest Research Institute, San Antonio, Texas.

A STUDY OF THE FEASIBILITY OF DEVELOPING OVERLAY MAPS TO INDICATE PERFORMANCE CAPABILITIES OF ORDNANCE EQUIPMENT IN SELECTED WORLD ENVIRONMENTS. Carroll G. Robinson and Howard M. Bunch.

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